



Aalborg Universitet

**AALBORG UNIVERSITY**  
DENMARK

**Proceedings, Expert Scientific Meeting, ESM 2012, 1-4 August 2012, Aalborg, Denmark**

Kersting, Uwe G.; Morlock, Michael M.; Jirova-Enzmann, Daniela; Dremstrup, Kim

*Publication date:*  
2012

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*

Kersting, U. G., Morlock, M. M., Jirova-Enzmann, D., & Dremstrup, K. (Eds.) (2012). *Proceedings, Expert Scientific Meeting, ESM 2012, 1-4 August 2012, Aalborg, Denmark*. Department of Health Science and Technology. Aalborg University.

**General rights**

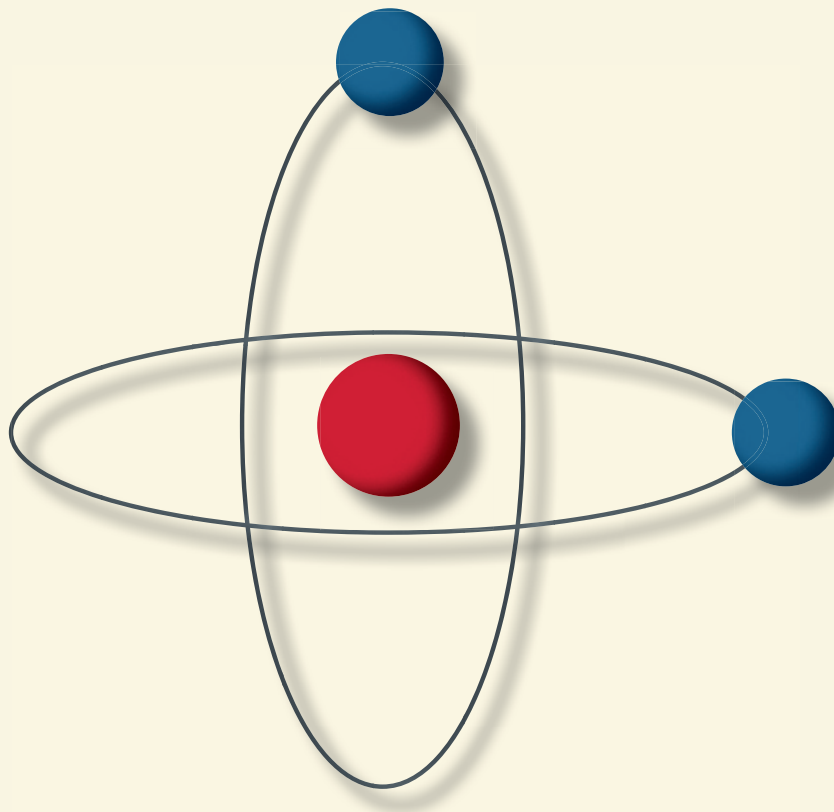
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

**Take down policy**

If you believe that this document breaches copyright please contact us at [vbn@aub.aau.dk](mailto:vbn@aub.aau.dk) providing details, and we will remove access to the work immediately and investigate your claim.

# proceedings



Aalborg, Denmark, August 1 - 4, 2012

Aalborg University and  
Aalborg Hospital, Århus University,  
Aalborg, Denmark

Publisher: Department of Health Science and Technology, Aalborg University  
Editors: Uwe G. Kersting, Michael M. Morlock, Daniela Jírová-Enzmann, Kim Dremstrup  
ISBN 978-87-7094-128-0

[www.esm2012.com](http://www.esm2012.com)

art.  
science



Publisher: Department of Health Science and Technology, Aalborg University  
Editors: Uwe G. Kersting, Michael M. Morlock, Daniela Jírová-Enzmann, Kim Dremstrup

ISBN 978-87-7094-128-0

# Content

Welcome .....	4
Host .....	6
Venue .....	7
Host and Conference Chair, Organizing Committee .....	7
Scientific and art in science award Committee .....	8
2010 Meeting Review .....	10
Workshops .....	11
Sponsors .....	11
art in science award .....	12
Poster and Presentation Awards, MPP .....	13
Networking Day, Friday August 3rd .....	14
Telephone Numbers and Internet.....	15
Events .....	15
Maps of Aalborg .....	16
Meeting Overview .....	18
Abstracts .....	32

# Program ESM 2012

## Wednesday August 1st

Workshops .....	19
-----------------	----

## Thursday August 2nd

Scientific Presentations and Poster Sessions .....	20
--	----

## Friday August 3rd

Networking Day (Sport Activities) .....	24
---	----

## Saturday August 4th

Scientific Presentations and Banquet .....	24
--	----



# Velkommen!

Velkommen til Aalborg!

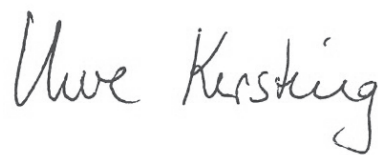
Dear Guests, Colleagues, Students and Friends,

The Expert Scientific Meeting 2012 (ESM 2012) has begun and will take place at the Department of Health Science and Technology at Aalborg University in Northern Jutland, Denmark! – We, the organizing and scientific committees, feel exceedingly honored that we received such a large number of high-quality abstracts, making this ESM one of the most successful so far. This conference is dedicated to research on dynamic load distribution in biomechanics, uniting researchers from various and, in some cases, separate scientific fields who would otherwise not meet at the same table.

The interdisciplinary flavor of the conference is particularly suited to be presented within the multidisciplinary research environment at Aalborg University. Many of you, at least some of the academic teachers, may have heard about the 'Aalborg Model' with this university being internationally recognized for its engagement in project-based and research-driven teaching concepts. The hosting department (<http://www.hst.aau.dk/>) unites as many as seven different degrees ranging from biomedical engineering over sports science to clinical sciences and includes subjects such as medical technology and medicine, our most recent accrual. Therefore, we kindly welcome you to this event together with our co-hosts from other institutions within the region.

From the first announcement up to now, when it all starts, we lived through many working hours, months of preparation with endless tasks to be sorted, successions of meetings, appointments to plan and adjust, review, layout - and a lot of fun. Most likely, there are many more things to come over the next few days. Along the way, I have made the acquaintance of so many people within the university, at our outside partners, and from the different venues which you will embrace throughout the course of the conference. We have received particular support from Visit Aalborg and Aalborg Kommune to help getting everything in place. After living in Denmark for four years, I have again experienced the Danes as overwhelmingly welcoming, helpful, and genuinely friendly people. Therefore, we are most confident that you will make a similar experience. My thanks are also directed to the team of our main sponsor who provided so much input making the preparations as delightful as they could be.

I am looking forward to exciting days in Northern Jutland. Welcome to Aalborg,



Uwe Kersting, PhD  
Associate Professor in Biomechanics  
Center for Sensory-Motor Interaction  
Aalborg University, Aalborg, Denmark



# Velkommen!

Dear participants of ESM 2012,

It is my great pleasure to welcome you all to Aalborg University on behalf of my colleagues at the Faculty of Medicine.

Welcome to a young, rapidly developing faculty. It is a fantastic opportunity to be involved in building a new faculty and at the same time continuing a longstanding, strong research and teaching effort. The Faculty of Medicine is based on the university's values: creativity, openness and cooperation. They are central to everything we do in terms of research, education and innovation.

The Faculty of Health Science was founded in 2010, and the university was opened in 1974. It is ranked no. 67 among the approximately 15.000 universities below the age of 50 years. The Faculty of Medicine emphasizes education and research to be meeting the needs of the surrounding dynamic society. Sports science has in recent years shown an increasing role for health. The first master students in sports science graduated this summer from the Faculty of Medicine.

The faculty sees itself as a holistic one. We offer a wide range of programs covering all aspects of health science, but with technology as a special core area. The central principle in all our programs is problem-based learning where project work, patient histories or case-based teaching are essential parts of study life.

Collaboration plays a significant role at the Faculty of Medicine. Collaboration with hospitals in the region, collaboration across university faculties, collaboration among department staff, and not least, collaboration with universities, companies, municipalities around the world and with University College of Northern Denmark.

North Denmark offers an interesting background for you. The nature is unique and varied. People in North Denmark like to have a reputation of being honest, reliable and at the same time like to party and enjoy life. In the bars and restaurants you will meet a friendly and open attitude different from many peoples expectation of a cold and shy attitude of Scandinavian people.

The faculty feels honored to host this meeting as its multi-disciplinary character matches the universities motto/ethos of a collaborative and open research environment. We appreciate the fact that this conference has attracted high level researchers from all continents to come together for a fruitful and exciting meeting.

Hope You will enjoy the meeting and your stay here.



Yours sincerely,

Egon Toft  
Professor, Dean  
Faculty of Medicine  
Aalborg University



# Host



Center for Sensory-Motor Interaction (SMI) focuses on translational research in neuroscience and engineering with the aim to develop new diagnostic and therapeutic methods in the areas of pain, motor control, sports sciences, and rehabilitation.

Center for Sensory-Motor Interaction (SMI) is an inter-disciplinary, international center with a scientific and technical-administrative staff of 80 persons. Approximately 50% of the researchers come from abroad. SMI is operating under the Department of Health Science and Technology, Faculty of Medicine, Aalborg University.

SMI was established as a Center of Excellence in 1993 with support from the Danish National Research Foundation. In 1997, the International Doctoral School in Biomedical Science and Engineering was established in affiliation to SMI. In 2006 the School was further able to offer the first doctoral program for elite students.

The Center has three major activities, namely research, training, and innovation.

The umbrella for the research area is set by four Research Interest Groups which are further subdivided into a total of 24 laboratories.

The International Doctoral School in Biomedical Science and Engineering covers the top level training at the center. In 2006, the School was awarded a grant from The Danish Ministry of Science, Technology and Innovation to start a doctoral program for elite students. At the MSc level, SMI offers a 5-year program in several degrees.

Innovation is based on grants from the North Jutland region and the Ministry of Science, Technology and Innovation. SMI launched an innovation program in 2006 aiming at developing SMI research results into commercial products in co-operation with biomedical and pharmacological industry.



# Venue

## Aalborg University

- Workshops

Aalborg University  
Department of Health Science and Technology  
Fredrik-Bajers-Vej 7A  
9220 Aalborg, Denmark

tel: +45 99 40 88 29  
fax: +45 98 15 40 08  
[www.hst.aau.dk](http://www.hst.aau.dk)



## Utzon Center

- Conference/Presentations

- Banquet Dinner

Slotspladsen 4  
9000 Aalborg

tel: +45 76 90 50 00  
[www.utzoncenter.dk/en/welcome.htm](http://www.utzoncenter.dk/en/welcome.htm)



# Host and Conference Chair

Uwe Kersting, PhD  
Associate Professor in Biomechanics

Center for Sensory-Motor Interaction  
Aalborg University, Aalborg, Denmark

e-mail: [uwek@hst.aau.dk](mailto:uwek@hst.aau.dk)  
tel: +45 99 40 80 94  
fax: +45 98 15 40 08

Co-hosts:  
Bjarne Møller-Madsen, Professor, overlæge, dr.med.  
Aarhus Universitet

Jørgen Feldbæk Nielsen, Klinisk Prof., Overlæge, dr.med.  
Århus Universitet

Sten Rasmussen, Associate Prof., MD.  
Aalborg Hospital, Aarhus University

# Organizing Committee

Uwe Kersting, Kim Dremstrup  
Michael Morlock, Susanne Nielsen Lundis, Natalie Mrachacz-Kersting, Louise Klit, Debbie Pedersen  
Daniela Jírová-Enzmann, Clelia Beraldi, Kathrin Hoermann

# Scientific and art in science award Committee

**Michael M. Morlock, PhD**

chair of the art in science scientific committee  
Director, Institute of Biomechanics  
TUHH Hamburg University of Technology  
Denickestrasse 15  
D-21073 Hamburg, Germany  
e-mail: morlock@tuhh.de

---

**Rami J. Abboud, PhD**

University of Dundee  
Institute of Motion Analysis & Research (IMAR)  
University Dept. of Orthopaedic & Trauma Surgery  
Ninewells Hospital & Medical School  
DD1 9SY, Dundee, UK  
e-mail: r.j.abboud@dundee.ac.uk

---

**Anton Arndt, PhD**

Karolinska Institute  
Department of Orthopaedic Surgery  
Karolinska University Hospital/Huddinge  
Stockholm, Sweden

---

**Gert-Peter Brüggemann, PhD**

Institute of Biomechanics and Orthopaedics  
German Sport University Cologne  
Am Sportpark Müngersdorf 6  
50933 Cologne, Germany  
e-mail: brueggemann@dshs-koeln.de

---

**Peter Cavanagh, PhD**

University of Washington  
Dept of Orthopaedics and Sports Medicine  
1959 N.E. Pacific St., Box 356500  
Seattle, WA 98195, USA  
e-mail: cavanagh@u.washington.edu

---

**Howard J. Hillstrom, PhD**

Director, Leon Root, MD Motion Analysis Laboratory  
Hospital for Special Surgery  
510 East 73rd Street, Ground floor  
New York, NY 10021, USA  
e-mail: HillstromH@HSS.edu

**Uwe Kersting, PhD**

Center for Sensory-Motor Interaction  
Aalborg University  
Fredrik-Bajers-Vej 7D3  
9220 Aalborg, Denmark  
e-mail: uwek@hst.aau.dk

**Dieter Rosenbaum, PhD**

Motion Analysis Lab  
Orthopaedic Department  
University Hospital Muenster  
Domagkstr. 3  
48149 Muenster, Germany  
e-mail: diro@uni-muenster.de

**Marc Libotte, PhD**

Cabinet d'Orthopédie  
Av. des Héliotropes 13  
1030 Brussels, Belgium  
e-mail: marc.libotte@skynet.be

**Julie Steele, PhD**

University of Wollongong  
Biomechanics Research Laboratory  
University of Wollongong  
Northfields Ave  
Wollongong, NSW, Australia  
e-mail: julie\_steele@uow.edu.au

**Professor Pascal Madeleine, PhD**

Center for Sensory-Motor Interaction  
Aalborg University  
Aalborg, Denmark  
e-mail: pm@hst.aau.dk

**Helen Woo, PhD**

Manager of Performance Engineering  
Human Performance Engineering Lab  
Reebok International Ltd., USA  
e-mail: helen.woo@reebok.com

**Thomas Mittlmeier, PhD**

University of Rostock  
Dept. Orthopaedic Trauma  
Schillingallee 35  
18055 Rostock, Germany  
e-mail: thomas.mittlmeier@med.uni-rostock.de

**Mark de Zee, PhD**

Aalborg University  
Department of Health Science and Technology  
Center for Sensory-Motor Interaction (SMI)  
Fredrik-Bajers-Vej 7D3, 9220 Aalborg, Denmark  
e-mail: mdz@hst.aau.dk

**Jeff Pisciotta**

Nike Inc.  
Sport Research Laboratory  
One Bowerman Drive  
MH-1 Beaverton, OR 97005.6453, USA  
e-mail: jeff.pisciotta@nike.com



# 2010 Meeting Review



The 12th EMED scientific meeting was held in Providence, Rhode Island on August 14-17, 2010. The meeting kicked off with a user workshop at the Center for Restorative and Regenerative Medicine at the Providence VA Medical Center. The workshop focused on data collection and many discussions revolved around the appropriate novel hardware and software for different applications. Demonstrations highlighted the clinical potential of synchronizing the novel systems with motion capture hardware. The day ended with the spectacular WaterFire display in downtown Providence.

Scientific presentations were held on Day 2 and Day 4 of the meeting with interesting and intriguing keynote lectures on the evolution of walking and running. Thirty-seven abstracts were accepted for podium presentations and fifteen papers were presented as posters. Podium discussions on "Pedography as a Diagnostic Method for Determining Foot Function: Technical, Methodological and Other Requirements" and "The Perfect Running Shoe is the Bare Foot?" sparked a lively dialogue among attendees. The art in science award, poster and presentation awards were awarded to Josh Slane, University of Wisconsin-Madison, Manfred Geuder, novel GmbH and Deydre Teyhen, U.S. Army Baylor University, respectively.



On activity day, the conference attendees were taken to Block Island, Rhode Island to experience beaches, sparkling clear waters, dramatic bluffs, preserved open spaces, and fun-filled activities including sailing and kayaking. The day was brought to a close with a New England lobster broil at The Atlantic Inn overlooking the beautiful Atlantic Ocean.

Evening events included a reception at the world-renowned RISD Art Museum. Guests were treated to a museum tour of the galleries and a piano concert by Henriette Gaertner. The meeting concluded with the banquet at the Hotel Providence.

Susan E. D'Andrea  
Director, Gait and Motion Analysis Laboratory  
The Center for Restorative and Regenerative Medicine  
Assistant Professor, Department of Orthopaedics,  
Brown University

# Workshops & Sponsors

## Workshops

Axel Kalpen

Uwe Kersting

Patrick McLaughlin

Natalie Mrachacz-Kersting

Maria Pasquale



## Sponsors

### Aalborg University

Aalborg, Denmark  
[www.en.aau.dk](http://www.en.aau.dk)

### Faculty of Medicine, AAU

[www.medicine.aau.dk](http://www.medicine.aau.dk)

### Department of Health Science and Technology, AAU

[www.hst.aau.dk](http://www.hst.aau.dk)

### novel gmbh

Munich, Germany  
[www.novel.de](http://www.novel.de)



novel.de

### Eir - Empowering Industry and Research, AAU

[www.eirbusinesspark.com](http://www.eirbusinesspark.com)





# art in science award



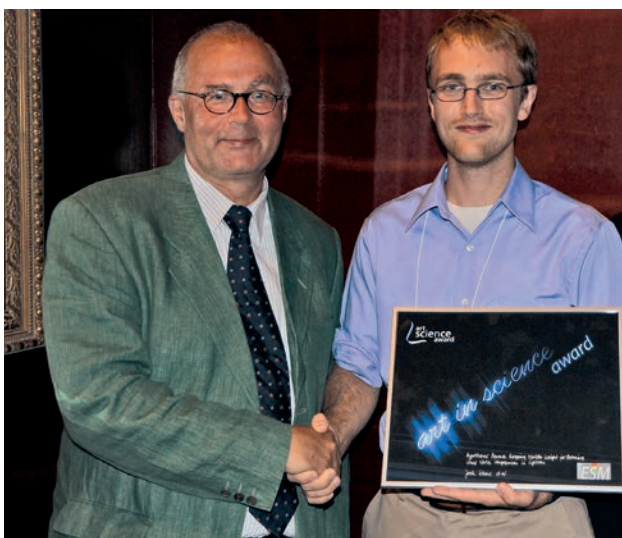
In 1991, the first novel award was presented in recognition of excellence in pressure distribution research. The novel award recipient was determined by an international review committee from the fields of biomechanics and medicine. The novel award for pressure distribution measurement research continued since then to be endowed by novel and the best scientific manuscript in the field of load distribution measurement will receive the 2012 art in science award with a prize of € 5,000. The paper must be entirely original, not published at the time of the meeting in any journal nor submitted for publication to any journal or book. The paper must describe a scientific study including pressure distribution measurement. Six abstracts were nominated for the art in science award.

From the year 2010 on, the "novel award" is named the "art in science award". It is intended to award the prize also to scientists presenting papers not only associated with pedography or foot biomechanics.

The nominated authors were requested to send a full length paper by June 25, 2012 and will present the paper at the meeting during a 25 minute talk. The review of the papers will be conducted by the scientific review committee. The art in science award will be presented to the winner at the final reception on Saturday evening, August 4, 2012.

## Previous Winners

Providence, 2010, Josh Slane, USA  
Dundee, 2008, Scott Wearing, UK  
Spitzingsee, 2006, Wolfgang Potthast, Germany  
Leeds, 2004, Joshua Burns, Australia  
Leeds, 2004, Mark Thomson, Germany  
Kananaskis, 2002, Katrina S. Maluf, USA  
Munich, 2000, Matthew Nurse, Canada  
Calgary, 1999, Brian Davis, USA  
Brisbane, 1998, Margaret Hodge, Australia  
Tokyo, 1997, Erez Morag, USA  
Pennstate, 1996, Dieter Rosenbaum, Germany  
Ulm, 1994, Michael Morlock, Germany  
Vienna, 1991, Benno Nigg, Canada



Josh Slane, USA, winner of the art in science award 2010



Deydre Teyhen, USA, the winner of the presentation award 2010

# Poster & Presentation Awards

## MPP - Most Promising Proposal

### Presentation Award

**Will be presented during the final reception on Saturday evening, August 4, 2012.**

The award is based on voting of the scientific committee.  
The award winner will receive a prize of € 1,000.

### Poster Award

**Will be presented during the final reception on Saturday evening, August 4, 2012.**

The award is based on voting of the scientific committee.  
The award winner will receive a prize of € 1,000.

### MPP Award

### Most Promising Proposal

Anyone who has not defended his or her PhD prior to the first conference day (August 1, 2012) is eligible for this award. The goal is to present a project proposal which includes the investigation of load distribution on the human or animal body. The topic area can be freely chosen and a document of maximum 2 pages (excl. reference list) can be submitted to the session chair one hour before the award session starts (7 printed copies have to be provided). No prior disclosure of the title, topic area or any details of the proposed study are allowed.

Proposals fitting the requirements will be presented in a separate award session on the 4th day of ESM 2012. The main author will have 3 minutes for presentation of the study background, concept and plan followed by a 3-min discussion. The presentation should be only verbal, no slides or posters are allowed. The award committee will consist of 3 members of the scientific committee plus 3 randomly selected ad hoc members.

The winner will be the most innovative, relevant and most convincingly presented proposal.  
The winner will be presented at the final conference banquet. The prize money is € 1,000.



Manfred Geuder, Germany, the winner of the poster award 2010



## Networking Day Friday, August 3rd 2012

**This year's ESM Networking Day** will take place in the **Rebild Bakker** area which is a national park. Transportation from the hotel Radisson Blu Aalborg to Rebild will be provided by bus.

We will experience various forms of locomotion in a natural forest environment. This tour will entail a certain degree of competitiveness but with room for bringing in individual preferences for levels of activity to ensure that everyone will have an enjoyable experience.

Along the way we will be taken back in time. Under the large trees in the forest, our robber camp opens its doors for a day filled with fun, challenges and experiences. Enjoy a unique atmosphere at the big bonfire and join in the

treasure hunt, ax throwing, lumber jack activities, archery and knife throwing. Or make your own bread on a stick over the camp fire's licking flames. Robbers roam all day and help to blacken the kids and get into the mood of ancient Danish times. Songs will be performed, entertainment and stories about the spunky rogue from Rold who once roamed the area. We will have a large, rustic buffet with everything a true predator desires.

After a full day of activities we will return late afternoon to Aalborg (bus transportation to Radisson Blu hotel Aalborg). The evening event will include dinner in **the Azzurra Restaurant at Nordkraft Aalborg** and an art exhibition in the same location.





# Telephone Numbers and Events

## Telephone Numbers

- Utzon Center (conference site) +45 76 90 50 00
- Aalborg University, Center for Sensory-Motor Interaction (workshop site) +45 99 40 88 27
- Radisson Blu Limfjord, Aalborg +45 98 16 43 33
- Uwe Kersting, conference host +45 99 40 80 94
- Daniela Jírová-Enzmann +49 171 650 41 99
- Emergency service 112
- Police Aalborg +45 96 30 14 48
- Visitor Bureau "Visit Aalborg" +45 99 31 75 00
- Taxi +45 98 10 10 10
- Airport Aalborg +45 98 17 11 44
- Train, DSB +45 70 13 14 15

## Wireless Internet Access

Free wireless access to ESM conference guests will be provided during the workshop day (at SMI) as well as during the presentations in the Utzon Center. To access the wireless network please select the **"AAU-CONF-1"** wireless network and use following password: **"tHc759ef"**.

**eduroam** access will be also available.

## Events

**Additional information can be found in packets distributed within the conference bag**

- Franciscan Friary Museum (medieval ruins)
- Aalborg Defence and Garrison Museum
- Aalborg Zoo
- Lindholm Høje Museum (Viking live experience)
- Aalborg Maritime Museum
- The Lille Vildmose Visitors' Center
- Egholm Festival (local music festival, 03/08/2012 - 04/08/2012)
- Kim Larsen & Kjukken (Concert with the Danish rock band, 10/08/2012)





# Map of Aalborg





# Map of Aalborg-Detail



# Meeting Overview

## Wednesday, August 1

**Site:**

**Aalborg University, Center for Sensory-Motor Interaction**

Transportation to Workshops from Hotel Radisson Blu 7:30

Registration for Workshop attendees 7:45 – 8:45

**Site:**

**Aalborg University, Center for Sensory-Motor Interaction**

Tour of the Labs 8:45 – 10:00

novel Workshops 10:00 – 12:00, 14:00 – 16:25

Scandinavian companies - Presentations to participants 12:00 - 13:00

Lunch at Atrium 13:00 - 14:00

Transportation from the Workshops to Hotel Radisson Blu 16:30

**Site:**

**Kunsten, Museum of Modern Art Aalborg**

Registration 17:30 – 20:00

Opening Reception 18:00 – 20:00

Welcome by Helle Frederiksen, first vice major and

Kim Dremstrup, head of department, AAU

Tour Museum

Music by Helle Lund Trio



## Thursday, August 2

**Site:**

**Utzon Center**

Registration 7:30 - 8:40

Scientific presentations 8:40 - 10:05, 11:00 - 12:00

Poster sessions 10:05 - 11:00, 14:45 - 15:40

Lunch at Utzon Café og Restaurant 12:00

Scientific presentations 13:10 - 14:45, 15:40 - 17:10

**Site:**

**Prinses Juliana boat**

Dinner 19:00

Guitar accompaniment, H.P. Lange

## Friday, August 3

**Site:**

**Rebild**

Pickup from the Radisson Blu Hotel (bus departure) 7:30

Bus Departure from Rebild 16:30

**Site:**

**Nordkraft**

Dinner 19:00

Exhibition at Kunsthall Nord

## Saturday, August 4

**Site:**

**Utzon Center**

Scientific presentations 8:30 - 12:30

Lunch at Utzon Café og Restaurant 12:30

Scientific presentations 13:40 - 16:10

MPP Award Presentations 16:10

**Site:**

**Utzon Center**

Banquet Dinner, Music and Award Presentations 19:00

Music by Henriette Gärtner und Henriette Kastrup quintet



# Program ESM 2012 Aalborg

Wednesday, August 1st 2012

7:30	Transportation to the Workshops (at SMI) from Hotel Radisson Blu Aalborg
7:45 - 8:45	<b>Registration for the Workshop attendees</b> at Center for Sensory-Motor Interaction, Aalborg University
8:45 - 10:00	<b>novel Workshops at SMI, Aalborg University and tour of the Labs</b> <b>Tour around the Labs at SMI, Center for Sensory-Motor Interaction</b> <i>(tour will be repeated in parallel to the workshops at 10:00 and 14:00)</i>
10:00 - 11:00	<b>Workshop I: Basics of load distribution measurement - physics and biomechanics</b> - types of sensors and arrays for pressure distribution measurement - influence of sensor properties on the results of the measurements - interpretation of different parameters of the pressure distribution
11:00 - 12:00	<b>Workshop II: Evaluation of load distribution data</b> - data acquisition and evaluation for emed Pedography - practical assessment of bare foot measurements in clinical routine and research - integration of additional measuring systems and data into novel databases
12:00 - 13:00	Scandinavian companies - Presentations to participants
13:00 - 14:00	<b>Lunch at Atrium</b>
14:00 - 14:45	<b>Workshop III: pedar applications in sports and rehabilitation</b> - designing a setup for measurements in the field - application examples for pedar measurements in different sports - pedar Posturography for the practical assessments of postural stability
14:45 - 15:30	<b>Workshop IV: pliance applications on hands, braces and seats</b> - Manugraphy – functional diagnostics of the hand – a new scientific approach - measurements on very contoured surfaces, like braces or inside sockets
15:30 - 16:15	<b>Workshop V: setup and trouble shooting for novel systems</b> - installations of software and device drivers - bluetooth setups for pedar and pliance systems - check of calibration of sensors - calibration of new sensors - synchronisation with other systems etc.
16:30	Transportation from the Workshops (at SMI) to Hotel Radisson Blu Aalborg
17:30 - 20:00	<b>Registration at KUNSTEN, Museum of Modern Art Aalborg</b>
18:00	<b>Opening Reception at Kunsten, Museum of Modern Art Aalborg</b> Hors d'oeuvres and drinks Welcome by Helle Frederiksen, first vice major and Kim Dremstrup, head of the department Aalborg University Music by Helle Lund Trio Tour Museum



## Thursday, August 2nd 2012

<b>7:30 – 8:40</b> <b>8:30</b>	<b>Registration at Utzon Center</b>  <b>Welcome</b> <i>Uwe Kersting, ESM 2012 Host</i> <i>Peter Seitz, novel GmbH</i>
08:40 - 09:25	<b>KEYNOTE LECTURE 1</b> <b>Sensory feedback during normal and spastic human walking</b> <i>Thomas Sinkjær, Aalborg University SMI and Danish National Research Foundation</i> Chair: <i>Rosenbaum D.</i>
<b>9:25 – 10:05</b>	<b>SESSION 1 Orthotics</b>  Chair: <i>Mickle K.J. &amp; Rosenbaum D.</i>
9:25 - 9:35	<b>Using pressure measurement technology in the development of a new orthotic device</b> <i>McLaughlin P.</i>
9:35 - 9:45	<b>Relationship between weight, activity level, insole changes and plantar pressures</b> <i>Requena-Martínez A., Morey-Klapsing G., Aran-Ais F., Penarrocha-Fernández H., Montiel-Parreno E.</i>
9:45 - 9:55	<b>Effectiveness of gait in cp-children – a pilot investigation</b> <i>Bosch K., Wühr J., Hafkemeyer U.</i>
9:55 - 10:05	<b>Different plantar pressure distribution images in children with cerebral palsy</b> <i>Patlatov A.A., Tartakovskiy V.N., Tsvetkova T.L.</i>
<b>10:05 - 11:00</b>	<b>Poster Session 1 &amp; Coffee</b>  Chair: <i>Mrachacz-Kersting N. &amp; Bus S.</i>
	<b>Fracture analysis of vertebra with finite element method and compare it with experimental data</b> <i>Behforootan S., Kasra M.</i>
	<b>The effect of weight-bearing exercise and calcium supplementation on the tibia geometry and mechanical strength</b> <i>Dabidi-Roshan V., Hosseinzadeh M., Eslami M.</i>
	<b>Apply time series modeling in gait kinematic analysis during slips</b> <i>Hu X., Qu X.</i>
	<b>Plantar pressure distribution of different foot models during cutting movements</b> <i>Lehner S., Dießl C., Chang D., Senner V.</i>
	<b>Comparison of gait stages in women of different age</b> <i>Musil R., Sebera M., Senkyr J., Pavlik J., Michalek J.</i>
	<b>Can orthoses and navicular drop affect foot motion pattern during running</b> <i>Eslami M., Dabidi-Roshan V.</i>
	<b>On the effectiveness of the newly devised ergonomic chair with chest support by evaluation of muscle activity and contact load</b> <i>Won B.H., Kim J.H., Lim S.Y., Hong J.S., Chun K.J.</i>
	<b>The influence of heel height and of construction of the heel on plantar pressure</b> <i>Foltynova B., Cernekova M., Hlavacek P.</i>

	<p><b>Effective combination of new bone substitute and screws in the jail technique: a biomechanical study of tibial depression fractures</b>  <i>Dohrt S., Lehnert T., Frey S., Fehske K., Jansen H., Blunk T., Meffert R.H.</i></p> <p><b>Body pressure measuring device for the prevention against bedsores</b>  <i>Koo D., Jang K., Lee K.</i></p> <p><b>Comparison of the contact area of sole and surface in combative sports using pedar</b>  <i>Musil R., Senkyr J., Zvonar M., Reguli Z.</i></p> <p><b>Laterality and skating techniques in cross-country skiing</b>  <i>Jandova S., Charousek J.</i></p> <p><b>Analysis of gait balance characteristics in old hemiplegia patients for development of rehabilitation training system</b>  <i>Choi H., Lee B., Lim D., Ko J., Song L., Chun K.</i></p> <p><b>Yes, we can ... influence foot loading patterns by deliberately walking with in-toeing or out-toeing gait modifications</b>  <i>Rosenbaum D.</i></p> <p><b>Are there any relevant pedobarographic changes below the metatarsals after hallux valgus surgery? A series of lapidus arthrodesis and associated metatarsal osteotomies</b>  <i>Dietze A., Michel A., Mittlmeier T.</i></p>
<b>11:00 - 12:00</b>	<p><b>SESSION 2 Clinical Applications</b></p> <p>Chair: <i>Hillstrom H. &amp; Madeleine P.</i></p>
11:00 - 11:10	<p><b>Do significant changes in foot geometry take place in multiple sclerosis patients with different neurological status?</b>  <i>Tsvetkova T.L., Stolyarov I.D., Petrov A.M., Ilves A.G., Prakhova L.N., Nikiforova I.G., Lebedev V.V.</i></p>
11:10 - 11:20	<p><b>Glucocorticoid medication reduces metacarpophalangeal joint stiffness in patients affected by rheumatoid arthritis</b>  <i>Fröhlich A., Taylor W.R., Buttgereit F., Ehrig R.M., Witaschek T., Duda G.N.</i></p>
11:20 - 11:30	<p><b>Clinical relevance of anatomy-based plantar pressure analysis in clubfoot</b>  <i>Stebbins J., Giacomozzi C.</i></p>
11:30 - 11:40	<p><b>Deficits in forward propulsion remain 2-5 years after unilateral achilles tendon rupture</b>  <i>Agres A.N., Taylor W.R., Gehlen T., Duda G.N., Manegold S.</i></p>
11:40 - 11:50	<p><b>Investigation of human-structure dynamic interaction using biomechanical model</b>  <i>Dang H.V., Zivanovic S.</i></p>
11:50 - 12:00	<p><b>A discriminant analysis to distinguish planus, rectus and cavus foot types</b>  <i>Hillstrom H.J., Song J., Mootanah R., Rao S., Kraszewski A.P., Hafer J.F., Backus S., Deland J.</i></p>
<b>12:00 - 13:10</b>	<p><b>Lunch, Utzon Café og Restaurant at Utzon Center</b></p>

13:10 - 14:45	<b>SESSION 3 art in science award Finalists I Methods I</b>  Chair: <i>Stebbins J. &amp; Bochdansky T.</i>
13:10 - 13:35	<b>art in science award finalist</b> Intraarticular force distribution in the femorotibial joint is related to knee adduction moment and knee flexion <i>Engel K., Brüggemann G.-P., Heinrich K., Rembitzki I.V., Liebau C.</i>
13:35 - 14:00	<b>art in science award finalist</b> Prognostic factors in the causation of recurrent plantar ulceration in patients with diabetes <i>Waaijman R., de Haart M., Arts M.L.J., Wever D., Verlouw A., Nollet F., Bus S.A.</i>
14:00 - 14:25	<b>art in science award finalist</b> Changes in COP displacement with the use of a foot drop stimulator in individuals with stroke <i>Nolan K.J., Yarossi M.</i>
14:25 - 14:35	<b>From 2006 to 2012: relevant steps and changes in plantar pressure measurement</b> <i>Giacomozzi C.</i>
14:35 - 14:45	<b>The IMAR 3D-force system: Have we cracked it?</b> <i>Arnold G.P., Abboud R.J.</i>
14:45 - 15:40	<b>Poster Session 2 &amp; Coffee</b> Chair: <i>Nolan K. &amp; van Deursen R.</i>  <b>Computational modeling of ergometer rowing</b> <i>Juliussen R., Aagaard P., de Zee M., Rasmussen J., Simonsen E.B., Vinther A., Alkjær T.</i>  <b>Relationship between pressure and vertical force related variables in different running shoe construction technologies</b> <i>Dinato R.C., Pereira I.L.R., Butugan K., Ribeiro A.P., Onodera A.N., Sacco I.C.N.</i>  <b>Pedobarographical findings after operative ankle fracture treatment preliminary results – a prospective clinical trail</b> <i>Dietze A., Annecke A., Mittlmeier T.</i>  <b>Static arch height and rearfoot alignment are associated with dynamic plantar pressure patterns during running in runners with plantar fasciitis</b> <i>Ribeiro A.P., Joao S.M.A., Sacco I.C.N.</i>  <b>Integrated gait analysis of flatfoot: the potential of appropriate foot models and anatomy-based pedography</b> <i>Giacomozzi C., Stebbins J., Berti L., Leardini A.</i>  <b>Plantar pressure distribution during walking in habitually barefoot populations</b> <i>Wunderlich R.E., Hatala K.G., Dingwall H.L., Richmond B.G.</i>  <b>A simple scaling relationship for CPEI between the emed-x and matscan</b> <i>Hillstrom H.J., Cacace L., Hafer J., Lenhoff M.W., Song J., Hannan M.T.</i>  <b>Balancing barefoot in single leg ballet poses generates less center of pressure oscillations</b> <i>Lobo Da Costa P.H., Nora F.G.S.A., Vieira M.F., Bosch K., Rosenbaum D.</i>

	<p><b>Measurement accuracy is related to a homogenous pressure during the calibration</b> <i>Engel K., Hübner T., Potthast W., Brüggemann G.-P.</i></p> <p><b>Bench press with an unstable load does not affect stability</b> <i>Kristiansen M., Svarrer S.M., Mora-Jensen M.H., Timm A.R.</i></p> <p><b>Studded and bladed football boots: Which one to trust?</b> <i>Abboud R.J., Bhutani T.S., Arnold G.P., Nasir S., Wang W.</i></p> <p><b>Sensitization and degenerative changes in the tibiofemoral joint influence plantar loading in patients with symptomatic tibiofemoral osteoarthritis</b> <i>Røslund T., Gregersen L.S., Eskehave T. N., Arendt-Nielsen L., Kersting U.G.</i></p> <p><b>Ankle joint loading during landing on inclined surfaces - mechanical effect of ankle braces in injury prone situations</b> <i>Theodorakos I., Rueterbories J., Andersen M.S., de Zee M., Kersting U.G.</i></p> <p><b>Body composition influences indirect but not direct measures of foot arch structure in adult females</b> <i>Wearing S.C., Reed L.F.</i></p> <p><b>Using pliance and a pliance developed saddle to optimize fit and comfort for a horse with severe spinal abnormalities</b> <i>Crowell A., Gavin A., Carter A.</i></p>
15:40 - 16:20	<p><b>KEYNOTE LECTURE 2</b> <b>Biomechanics in skiing – load analysis, performance and perspectives</b> <i>Stefan Lindinger, University of Salzburg</i> Chair: <i>Potthast W.</i></p>
16:20 - 17:10	<p><b>SESSION 4 Exercise &amp; Athletic Footwear</b>  Chair: <i>Brauner T. &amp; Potthast W.</i></p>
16:20 - 16:30	<p><b>Relationship between impact related variables and perceived comfort in different running shoe construction technologies</b> <i>Dinato R.C., Pereira I.L.R., Butugan K., Ribeiro A.P., Onodera A.N., Sacco I.C.N.</i></p>
16:30 - 16:40	<p><b>Footfall patterns in natural motion running shoes compared to conventional running shoes</b> <i>Mifsud N.L., Kristensen N.H., Kersting U.G.</i></p>
16:40 - 16:50	<p><b>Plantar pressure depends on the playing surface in tennis</b> <i>Damm L., Starbuck C., Stocker N.</i></p>
16:50 - 17:00	<p><b>Transient impact estimation using plantar pressure time series in runners with plantar fasciitis</b> <i>Ribeiro A.P., Dinato R.C., João S.M.A., Sacco I.C.N.</i></p>
17:00 - 17:10	<p><b>Synchronization of measurement systems for determining the physical work load</b> <i>Löwis P., Kaiser H., Consmüller T., Blüthner R., Hanisch C., Schust M., Kalpen A.</i></p>
19:00	<p><b>Evening event</b> <b>Dinner at Prinses Juliana floating boat in Aalborg Harbour</b> <b>Guitar accompaniment, H.P. Lange</b></p>

## Friday, August 3rd 2012

<p>7:30 16:30</p> <p><b>19:00</b></p>	<p><b>Networking day and sport activities in Rebild</b></p> <p>Pickup from the Radisson Blu Hotel Aalborg (bus departure) 7:30 Bus Departure from Rebild</p> <p><b>Dinner at Nordkraft, Aalborg</b> <b>Exhibition at Kunsthal Nord</b></p>
---	--

## Saturday, August 4th 2012

<p><b>8:30 - 9:15</b></p>	<p><b>KEYNOTE LECTURE 3</b> <b>Pressure measurement in pressured tissues: new perspectives in cancer research</b> <i>Julie Steele, University of Wollongong</i> Chair: <i>Wunderlich R.</i></p>
<p><b>9:15 - 10:15</b></p>	<p><b>SESSION 5 Modulation of Gait</b>  Chair: <i>Wunderlich R. &amp; Giacomozzi C.</i></p>
<p>9:15 - 9:25</p>	<p><b>Relationships of selected parameters of gait towards the laterality of lower extremities</b> <i>Kolarova K., Zvonar M., Pavlik J., Hrebickova S.</i></p>
<p>9:25 - 9:35</p>	<p><b>Plantar pressure distribution in Indian people walking with varied extent of footwear use</b> <i>Mullerpatan R.P.</i></p>
<p>9:35 - 9:45</p>	<p><b>Longitudinal study of changes in footstep force distribution during pregnancy</b> <i>Cernekova M., Hlavacek P., Naplavova E., Kutalkova E.</i></p>
<p>9:45 - 9:55</p>	<p><b>How early can the child's foot type be detected? Retrospective analysis of longitudinally assessed arch index values</b> <i>Rosenbaum D., Bosch K.</i></p>
<p>9:55 - 10:05</p>	<p><b>Cross-sectional comparison of selected gait characteristics of women of different age</b> <i>Korvas P., Musil R., Dosla J., Cacek J.</i></p>
<p>10:05 - 10:15</p>	<p><b>Does genu valgum and/or flat foot play a role in dynamic plantar pressures and static footprints</b> <i>Bernecker R., Weghuber D., Landauer F., Huber G., Wicker A.</i></p>
<p><b>10:15 - 10:55</b></p>	<p><b>Coffee</b></p>
<p><b>10:55 - 12:30</b></p>	<p><b>SESSION 6 art in science award Finalists II</b> <b>Methods II</b>  Chair: <i>Morlock M. &amp; de Zee M.</i></p>
<p>10:55 - 11:20</p>	<p><b>art in science award finalist</b> <b>The effects of foot type and heritability on balance and plantar pressure distribution in female twins aged 18-35 years old</b> <i>Mimar R., Shakibi B., Sadeghi H., Shakibi V.</i></p>

11:20 - 11:45	<b>art in science award finalist</b> <b>Correlation of the golf handicap and the applied pressure values at the grasp of a golf club during teeing off</b> <i>Lehner S., Senner V.</i>
11:45 - 12:10	<b>art in science award finalist</b> <b>Cycling &amp; impotency: the way forward!</b> <i>Cotton N.I., Arnold G.P., Nasir S., Wang W., Khan F., Abboud R.J.</i>
12:10 - 12:20	<b>Comparison of plantar pressure and shape changes of the foot between normal walking and walking with lifted swinging leg</b> <i>Fritz B., Knorr L., Grau S.</i>
12:20 - 12:30	<b>Does foot type affect stress distribution in the first metatarsophalangeal joint?</b> <i>Mootanah R., Truchetet A., Rao S., Chapman C., Regatte R.R., Hillstrom H.J.</i>
<b>12:30 - 13:40</b>	<b>Lunch, Utzon Café og Restaurant at Utzon Center</b>
<b>13:40 - 14:20</b>	<b>KEYNOTE LECTURE 4</b> <b>The rise of meaningfulness – or what to do when complexity surpasses human intelligence</b> <i>Anne Skare Nielsen, future navigator</i> Chair: <i>Kersting U.G.</i>
<b>14:20 - 15:10</b>	<b>SESSION 7 Diabetes</b>  Chair: <i>Kersting U.G. &amp; Abboud R.J.</i>
14:20 - 14:30	<b>The effectiveness of offloading-improved custom footwear on plantar foot ulcer recurrence in diabetes: a multicenter RCT</b> <i>Bus S.A., Arts M.L.J., Waaijman R., de Haart M., Busch-Westbroek T., van Baal S.G., Nollet F.</i>
14:30 - 14:40	<b>Influence of physical therapy intervention on foot rollover process during gait of diabetic neuropathic patients</b> <i>Sartor C.D., Watari R., Passaro A.C., Picon A.P., Vilibor R.H.H., Sacco I.C.N.</i>
14:40 - 14:50	<b>The effect of strengthening exercises on gait biomechanics in patients with diabetic peripheral neuropathy</b> <i>Meana-Esteban A., Price P., van Deursen R.W.M.</i>
14:50 - 15:00	<b>Midsole geometry affects plantar pressure pattern during walking in diabetic footwear</b> <i>Braunstein B., Preece S., Chapman J., Hoehne A., Nester C., Brueggemann G.-P.</i>
15:00 - 15:10	<b>Plantar pressure during gait in diabetic neuropathy: effect of severity degree classified by a fuzzy expert model</b> <i>Sacco I.C.N., Hamamoto A.N., Watari R., Tonicelli L., Sartor C.D., Ortega N.R.S.</i>
<b>15:10 - 15:30</b>	<b>Coffee</b>

<b>15:30 - 16:10</b>	<b>SESSION 8 Exercise and Loading</b>  Chair: <i>Sacco I.C.N. &amp; Brüggemann G.-P.</i>
15:30 - 15:40	<b>Influence of muscle forces on load distribution in the knee</b> <i>Potthast W., Engel K., Heinrich K., Dargel J., Brüggemann G.-P.</i>
15:40 - 15:50	<b>Squat movement quality quantified by plantar pressure distribution in patients following total hip arthroplasty</b> <i>Brauner T., Zillober M., Rämisch E., Horstmann T.</i>
15:50 - 16:00	<b>Force and plantar contact area characteristics during push-off in cross-country skiing</b> <i>Korvas P., Hellebrandt V., Zvonar M.</i>
16:00 - 16:10	<b>Relationship between muscle size and toe flexor strength</b> <i>Mickle K.J., Angin S., Crofts G., Nester C.J.</i>
<b>16:10 - 17:10</b>	<b>MPP Award Presentations</b>
17:10	<b>Closing remarks</b> <i>Peter Seitz</i> <i>Uwe Kersting</i>
<b>19:00</b>	<b>Evening Event</b> <b>Utzon Center</b> Banquet Dinner Music by Henriette Gärtner and Henriette Kastrup Quintet Award Presentations





# Presentations

K1	<b>Keynote Lecture</b> <b>Sensory feedback during normal and spastic human walking</b> <i>Thomas Sinkjær, Aalborg University SMI and Danish National Research Foundation</i>	33
T1	<b>Using pressure measurement technology in the development of a new orthotic device</b> <i>McLaughlin P.</i>	34
T2	<b>Relationship between weight, activity level, insole changes and plantar pressures</b> <i>Requena-Martínez A., Morey-Klapsing G., Arán-Ais F., Penarrocha-Fernandez H., Montiel-Parreño E.</i>	35
T3	<b>Effectiveness of gait in cp-children – a pilot investigation</b> <i>Bosch K., Wühr J., Hafkemeyer U.</i>	36
T4	<b>Different plantar pressure distribution images in children with cerebral palsy</b> <i>Patlatov A.A., Tartakovskiy V.N., Tsvetkova T.L.</i>	37
T5	<b>Do significant changes in foot geometry take place in multiple sclerosis patients with different neurological status?</b> <i>Tsvetkova T.L., Stolyarov I.D., Petrov A.M., Ilves A.G., Prakhova L.N., Nikiforova I.G., Lebedev V.V.</i>	38
T6	<b>Glucocorticoid medication reduces metacarpophalangeal joint stiffness in patients affected by rheumatoid arthritis</b> <i>Fröhlich A., Taylor W.R., Buttgereit F., Ehrig R.M., Witaschek T., Duda G.N.</i>	39
T7	<b>Clinical relevance of anatomy-based plantar pressure analysis in clubfoot</b> <i>Stebbins J., Giacomozzi C.</i>	40
T8	<b>Deficits in forward propulsion remain 2-5 years after unilateral achilles tendon rupture</b> <i>Agres A.N., Taylor W.R., Gehlen T., Duda G.N., Manegold S.</i>	41
T9	<b>Investigation of human-structure dynamic interaction using biomechanical model</b> <i>Dang H.V., Zivanovic S.</i>	42
T10	<b>A discriminant analysis to distinguish planus, rectus and cavus foot types</b> <i>Hillstrom H.J., Song J., Mootanah R., Rao S., Kraszewski A.P., Hafer J.F., Backus S., Deland J.</i>	43
T11	<b>Intraarticular force distribution in the femorotibial joint is related to knee adduction moment and knee flexion</b> <i>Engel K., Brüggemann G.-P., Heinrich K., Rembitzki I.V., Liebau C.</i>	44
T12	<b>Prognostic factors in the causation of recurrent plantar ulceration in patients with diabetes</b> <i>Waaijman R., de Haart M., Arts M.L.J., Wever D., Verlouw A., Nollet F., Bus S.A.</i>	45
T13	<b>Changes in cop displacement with the use of a foot drop stimulator in individuals with stroke</b> <i>Nolan K.J., Yarossi M.</i>	46
T14	<b>From 2006 to 2012: relevant steps and changes in plantar pressure measurement</b> <i>Giacomozzi C.</i>	47
T15	<b>The IMAR 3D-force system: Have we cracked it?</b> <i>Arnold G.P., Abboud R.J.</i>	48
K2	<b>Keynote Lecture</b> <b>Biomechanics in skiing – load analysis, performance and perspectives</b> <i>Stefan Lindinger, University of Salzburg</i>	49
T16	<b>Relationship between impact related variables and perceived comfort in different running shoe construction technologies</b> <i>Dinato R.C., Pereira I.L.R., Butugan K., Ribeiro A.P., Onodera A.N., Sacco I.C.N.</i>	50



# Presentations

T17	<b>Footfall patterns in natural motion running shoes compared to conventional running shoes</b> <i>Mifsud N.L., Kristensen N.H., Kersting U.G.</i>	51
T18	<b>Plantar pressure depends on the playing surface in tennis</b> <i>Damm L., Starbuck C., Stocker N.</i>	52
T19	<b>Transient impact estimation using plantar pressure time series in runners with plantar fasciitis</b> <i>Ribeiro A.P., Dinato R.C., João S.M.A., Sacco I.C.N.</i>	53
T20	<b>Synchronization of measurement systems for determining the physical work load</b> <i>Löwis P., Kaiser H., Consmüller T., Blüthner R., Hanisch C., Schust M., Kalpen A.</i>	54
K3	<b>Keynote Lecture</b> <b>Pressure measurement in pressured tissues: new perspectives in cancer research</b> <i>Julie Steele, University of Wollongong</i>	55
T21	<b>Relationships of selected parameters of gait towards the laterality of lower extremities</b> <i>Kolarova K., Zvonar M., Pavlik J., Hrebickova S.</i>	56
T22	<b>Plantar pressure distribution in Indian people walking with varied extent of footwear use</b> <i>Mullerpatan R.P.</i>	57
T23	<b>Longitudinal study of changes in footstep force distribution during pregnancy</b> <i>Cernekova M., Hlavacek P., Naplavova E., Kutalkova E.</i>	58
T24	<b>How early can the child's foot type be detected? Retrospective analysis of longitudinally assessed arch index values</b> <i>Rosenbaum D., Bosch K.</i>	59
T25	<b>Cross-sectional comparison of selected gait characteristics of women of different age</b> <i>Korvas P., Musil R., Dosla J., Cacek J.</i>	60
T26	<b>Does genu valgum and/or flat foot play a role in dynamic plantar pressures and static footprints in obese and non obese children?</b> <i>Bernecker R., Weghuber D., Landauer F., Huber G., Wicker A.</i>	61
T27	<b>The effects of foot type and heritability on balance and plantar pressure distribution in female twins aged 18-35 years old</b> <i>Mimar R., Shakibi B., Sadeghi H., Shakibi V.</i>	62
T28	<b>Correlation of the golf handicap and the applied pressure values at the grasp of a golf club during teeing off</b> <i>Lehner S., Senner V.</i>	63
T29	<b>Cycling &amp; impotency: the way forward!</b> <i>Cotton N.I., Arnold G.P., Nasir S., Wang W., Khan F., Abboud R.J.</i>	64
T30	<b>Comparison of plantar pressure and shape changes of the foot between normal walking and walking with lifted swinging leg</b> <i>Fritz B., Knorr L., Grau S.</i>	65
T31	<b>Does foot type affect stress distribution in the first metatarsophalangeal joint?</b> <i>Mootanah R., Truchetet A., Rao S., Chapman C., Regatte R.R., Hillstrom H.J.</i>	66
K4	<b>Keynote Lecture</b> <b>The rise of meaningfulness – or what to do when complexity surpasses human intelligence</b> <i>Anne Skare Nielsen, future navigator</i>	67

# Presentations

T32	<b>The effectiveness of offloading-improved custom footwear on plantar foot ulcer recurrence in diabetes: a multicenter RCT</b> <i>Bus S.A., Arts M.L.J., Waaijman R., de Haart M., Busch-Westbroek T., van Baal S.G., Nollet F.</i>	68
T33	<b>Influence of physical therapy intervention on foot rollover process during gait of diabetic neuropathic patients</b> <i>Sartor C.D., Watari R., Pássaro A.C., Picon A.P., Vilibor R.H.H., Sacco I.C.N.</i>	69
T34	<b>The effect of strengthening exercises on gait biomechanics in patients with diabetic peripheral neuropathy</b> <i>Meana-Esteban A., Price P., van Deursen R.W.M.</i>	70
T35	<b>Midsole geometry affects plantar pressure pattern during walking in diabetic footwear</b> <i>Braunstein B., Preece S., Chapman J., Hoehne A., Nester C., Brüggemann G.-P.</i>	71
T36	<b>Plantar pressure during gait in diabetic neuropathy: effect of severity degree classified by a fuzzy expert model</b> <i>Sacco I.C.N., Hamamoto A.N., Watari R., Tonicelli L., Sartor C.D., Ortega N.R.S.</i>	72
T37	<b>Influence of muscle forces on load distribution in the knee</b> <i>Potthast W., Engel K., Heinrich K., Dargel J., Brüggemann G.-P.</i>	73
T38	<b>Squat movement quality quantified by plantar pressure distribution in patients following total hip arthroplasty</b> <i>Brauner T., Zillober M., Rämisch E., Horstmann T.</i>	74
T39	<b>Force and plantar contact area characteristics during push-off in cross-country skiing</b> <i>Korvas P., Hellebrandt V., Zvonar M.</i>	75
T40	<b>Relationship between muscle size and toe flexor strength</b> <i>Mickle K.J., Angin S., Crofts G., Nester C.J.</i>	76



# Poster Presentations

P1	<b>Fracture analysis of vertebra with finite element method and compare it with experimental data</b> <i>Behforootan S., Kasra M.</i>	77
P2	<b>The effect of weight-bearing exercise and calcium supplementation on the tibia geometry and mechanical strength</b> <i>Dabidi-Roshan V., Hosseinzadeh M., Eslami M.</i>	78
P3	<b>Apply time series modeling in gait kinematic analysis during slips</b> <i>Hu X., Qu X.</i>	79
P4	<b>Plantar pressure distribution of different foot models during cutting movements</b> <i>Lehner S., Dießl C., Chang D., Senner V.</i>	80
P5	<b>Comparison of gait stages in women of different age</b> <i>Musil R., Sebera M., Senkyr J., Pavlik J., Michalek J.</i>	81
P6	<b>Can orthoses and navicular drop affect foot motion pattern during running</b> <i>Eslami M., Dabidi-Roshan V.</i>	82
P7	<b>On the effectiveness of the newly devised ergonomic chair with chest support by evaluation of muscle activity and contact load</b> <i>Won B.H., Kim J.H., Lim S.Y., Hong J.S., Chun K.J.</i>	83
P8	<b>The influence of heel height and of construction of the heel on plantar pressure</b> <i>Foltynova B., Cernekova M., Hlavacek P.</i>	84
P9	<b>Effective combination of new bone substitute and screws in the jail technique: a biomechanical study of tibial depression fractures</b> <i>Doht S., Lehnert T., Frey S., Fehske K., Jansen H., Blunk T., Meffert R.H.</i>	85
P10	<b>Body pressure measuring device for the prevention against bedsores</b> <i>Koo D., Jang K., Lee K.</i>	86
P11	<b>Comparison of the contact area of sole and surface in combative sports using pedar</b> <i>Musil R., Senkyr J., Zvonar M., Reugli Z.</i>	87
P12	<b>Laterality and skating techniques in cross-country skiing</b> <i>Jandova S., Charousek J.</i>	88
P13	<b>Analysis of gait balance characteristics in old hemiplegia patients for development of rehabilitation training system</b> <i>Choi H., Lee B., Lim D., Ko J., Song L., Chun K.</i>	89
P14	<b>Yes, we can ... influence foot loading patterns by deliberately walking with in-toeing or out-toeing gait modifications</b> <i>Rosenbaum D.</i>	90
P15	<b>Are there any relevant pedobarographic changes below the metatarsals after hallux valgus surgery? A series of lapidus arthrodesis and associated metatarsal osteotomies</b> <i>Dietze A., Michel A., Mittlmeier T.</i>	91
P16	<b>Computational modeling of ergometer rowing</b> <i>Juliussen R., Aagaard P., de Zee M., Rasmussen J., Simonsen E.B., Vinther A., Alkjær T.</i>	92
P17	<b>Relationship between pressure and vertical force related variables in different running shoe construction technologies</b> <i>Dinato R.C., Pereira I.L.R., Butugan K., Ribeiro A.P., Onodera A.N., Sacco I.C.N.</i>	93

P18	<b>Pedobarographical findings after operative ankle fracture treatment preliminary results– a prospective clinical trail</b>	94
	<i>Dietze A., Annecke A., Mittlmeier T.</i>	
P19	<b>Static arch height and rearfoot alignment are associated with dynamic plantar pressure patterns during running in runners with plantar fasciitis</b>	95
	<i>Ribeiro A.P., João S.M.A., Sacco I.C.N.</i>	
P20	<b>Integrated gait analysis of flatfoot: the potential of appropriate foot models and anatomy-based pedography</b>	96
	<i>Giacomozzi C., Stebbins J., Berti L., Leardini A.</i>	
P21	<b>Plantar pressure distribution during walking in habitually barefoot populations</b>	97
	<i>Wunderlich R.E., Hatala K.G., Dingwall H.L., Richmond B.G.</i>	
P22	<b>A simple scaling relationship for cpei between the emed-x and matscan</b>	98
	<i>Hillstrom H.J., Cacace L., Hafer J., Lenhoff M.W., Song J., Hannan M.T.</i>	
P23	<b>Balancing barefoot in single leg ballet poses generates less center of pressure oscillations</b>	99
	<i>Lobo Da Costa P.H., Nora F.G.S.A., Vieira M.F., Bosch K., Rosenbaum D.</i>	
P24	<b>Measurement accuracy is related to a homogenous pressure during the calibration</b>	100
	<i>Engel K., Hübner T., Potthast W., Brüggemann G.-P.</i>	
P25	<b>Bench press with an unstable load does not affect stability</b>	101
	<i>Kristiansen M., Svarrer S.M., Mora-Jensen M.H., Timm A.R.</i>	
P26	<b>Studded and bladed football boots: which one to trust?</b>	102
	<i>Abboud R.J., Bhutani T.S., Arnold G.P., Nasir S., Wang W.</i>	
P27	<b>Sensitization and degenerative changes in the tibiofemoral joint influence plantar loading in patients with symptomatic tibiofemoral osteoarthritis</b>	103
	<i>Røslund T., Gregersen L.S., Eskehave T.N., Arendt-Nielsen L., Kersting U.G.</i>	
P28	<b>Ankle joint loading during landing on inclined surfaces - mechanical effect of ankle braces in injury prone situations</b>	104
	<i>Theodorakos I., Rueterbories J., Andersen M.S., de Zee M., Kersting U.G.</i>	
P29	<b>Body composition influences indirect but not direct measures of foot arch structure in adult females</b>	105
	<i>Wearing S.C., Reed L.F.</i>	
P30	<b>Using pliance and a pliance developed saddle to optimize fit and comfort for a horse with severe spinal abnormalities</b>	106
	<i>Crowell A., Gavin A., Carter A.</i>	

# Abstracts

The following contains the abstracts for each platform and poster presentation throughout the conference.

## SENSORY FEEDBACK DURING NORMAL AND SPASTIC HUMAN WALKING

Thomas Sinkjær<sup>1,2</sup>

1. Danish National Research Foundation, Copenhagen, Denmark
2. Center for Sensory-Motor Interaction, Aalborg University, Aalborg, Denmark

Sensory feedback from peripheral afferents contributes to the control of walking by controlling phase transitions and by reinforcing the locomotor muscle activity. Through polysynaptic projections, muscle afferents make a significant contribution to the activation of the muscle ankle extensors in the stance phase of walking. Many studies have examined the importance of muscle afferent feedback of the ankle extensors through H-reflex studies. However, interpreting such studies can be difficult when trying to quantitate the actual contribution of the afferent feedback to the ongoing level of muscle activity.

Consequently, other studies have attempted to evaluate the contribution of muscle afferent feedback to the EMG activity during walking by adding a stretch to the muscle(s) of interest during different phases of the walking cycle. If the forces mediated by these responses are recorded, such data

provide evidence of the significance of the muscle afferents in generating the correction of possible unexpected external perturbations of the gait, but they do not necessarily reveal information about the involvement of the muscle afferent activity in generating the muscle activity to the ongoing locomotor movements.

In this presentation, the importance of muscle afferent feedback to the ongoing muscle activity within the same step cycle during walking will be addressed. I will discuss how muscle afferents through neural circuitries contribute to reinforcing the locomotor muscle activity in the able-bodied and how reduced afferent feedback in spastic persons hampers their walking.

Finally, the paper discusses how sensory peripheral nerve stimulation can be used to enforce re-learning of walking in acute stroke patients.



## USING PRESSURE MEASUREMENT TECHNOLOGY IN THE DEVELOPMENT OF A NEW ORTHOTIC DEVICE

Patrick McLaughlin (1)

1. School of Biomedical and Health Sciences and ISEAL, Victoria University, Melbourne Australia

### INTRODUCTION

Recent media investigations and reports have heightened the level of public awareness of breast augmentation (implant) failure rates and complications. Advances in both surgical approach and material composition have been unable to prevent many of the fundamental complications patients' experience. The introduction of foreign material of any type significantly alters the anatomy and structural biomechanics of the anterior chest wall. Tissues adjoining the implant are highly susceptible to damage as the material is displaced. This is most evident during activities where the patient is in a prone load bearing position (ie. face down).

Activities such as sleeping, as well as therapeutic procedures and examinations such as those used in massage, chiropractic and physiotherapy, compress and displace the soft tissues of the anterior chest. This can cause significant deformation of these vulnerable tissues and structures, and, where present, the implant material. By reducing exposure to the mechanics of breast compression and deformation in prone activities, it may be possible to reduce the incidence of complications and failure rates for implant patients.

A new truncal orthotic has been designed and developed in Australia specifically for the reduction of displacement, compression and loading forces through the breast tissue. The device is designed to protect the vulnerable implant material and adjacent natural tissue that is often damaged through deformation during prone activities.

To assess the effectiveness of this device fifteen (n=15) females with breast sizes ranging from C – F cup size volunteered for the study. The sample included females with both natural (n=8) and augmented breast tissue (N=7). The aim of the study was to measure tissue deformation and loading through the anterior chest/ breast tissue during prone activities.

MRI was performed showing segmental transverse and para-sagittal mid-breast views, providing linear measurements (mm) of breast tissue displacement and deformation (Siemens 1.5 T Magnetom Espree, Germany). At a separate testing site, capacitance sensor strips (pliance®, novel, Germany) were utilised as a means of measuring force (N) and pressure (kPa) between the breast tissue and the surface of a standard treatment table. Two strips of

3 x 15 sensors with an individual area of 1cm<sup>2</sup> and sampling at 50Hz were placed in the area under where the participant's right breast was positioned.

Measurements were taken whilst the subjects were load bearing in various prone positions. Comparisons between lying with and without the orthotic were made for all conditions as a means of comparison.

### RESULTS

Each participant's response to the orthotic was dependent on breast size and size of orthotic used. As an example, a size 4 (large) orthotic decreased load on the breast tissue by 82% and reduced peak pressure (kPa) by 42%. The same orthotic decreased medio-lateral spread of breast tissue and implant and increased height of the breast and implant as evidenced in Figures 1a and b. The trend of these results was consistent across participants.

These results highlight the loads imposed on breast tissue and indicate that this new orthotic device decreases the breast tissue and, where present, implant exposure to the potentially damaging and painful forces of compression and displacement during prone loading activities.

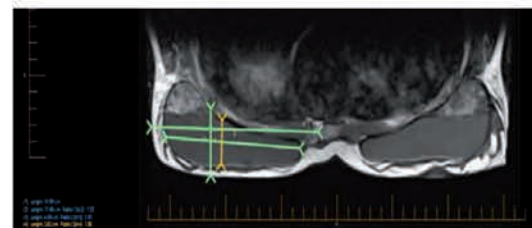


Figure 1a: Participant with DD cup size, augmented. No orthotic condition, transverse view from MRI.

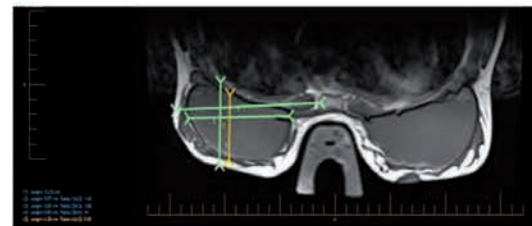


Figure 1b: Participant with DD cup size, augmented. Size 4 orthotic condition, transverse view from MRI.

## RELATIONSHIP BETWEEN WEIGHT, ACTIVITY LEVEL, INSOLE CHANGES AND PLANTAR PRESSURES.

**Aranza. Requena-Martínez (1), Gaspar. Morey-Klapsing (2), Francisca. Arán-Ais (2), Héctor Peñarrocha-Fernández (3), Enrique. Montiel-Parreño(2)**

1. TPSP, SPAIN
2. INESCOPE, SPAIN
3. IVPIE, SPAIN

### INTRODUCTION

Insole properties change over time and use. Consequently their effects should also change. Besides supporting the foot, one of the duties of insoles is to produce a proper distribution of plantar pressures

The aim of this study is to quantify the relationship between subject's weight, activity level, changes in shape and properties of the insoles and the plantar pressures. This study is part of a bigger study in which a wide range of insole materials has been characterised. This pilot wants to help in establishing a predictive technique that would allow choosing the proper material as a function of the patients' weight and level of activity.

### METHODS

Insoles made of two of the characterised materials (two EVA of differing density and hardness) were chosen. The insoles were generic insoles designed and milled using the ORTHOINSOLES software from INESCOPE based on data from a previous foot anthropometry study. All insoles of the same size were identical.

24 healthy female and male subjects between 25 and 55 years participated in the study. Subjects were assigned to one of four activity groups. From low activity (mainly seating, to high activity (mainly standing/walking).

All subjects wore the insoles for 10 consecutive working days, during at least 8 hours a day, wearing the same kind of socks and same footwear (indoor sport shoes, KELME STAR-360°). During the time they wore the insoles they also wore an RT3 waist mounted activity monitor.

Plantar pressures were measured the very first day as well as the last day using the PEDAR System (Novel, Munich, Germany) operating at 50 Hz. Subjects walked on a treadmill at 4 km/h during at least 3 minutes, data were collected during the last 60 seconds. Data

Insole thickness at defined zones was measured every two days just prior to putting on the test shoes and insoles and 5 minutes after taking them off at the end of the working day.

### RESULTS

<b>MCP</b>	Maximal Cell Pressure
<b>MMP</b>	Maximal Mask Pressure
<b>IMP</b>	Impulse
<b>FF</b>	Forefoot
<b>MF</b>	Midfoot
<b>HE</b>	Heel

*Table 1: Glossary of abbreviations.*

	<b>Forefoot</b>	<b>Midfoot</b>	<b>Heel</b>
<b>MCP</b>	0,905	0,413	0,126
<b>MMP</b>	0,011*	0,595	0,536
<b>IMP</b>	0,209	0,253	0,081

*Table 2: P values for the comparison between initial and final plantar pressure data considering all subjects together.*

	<b>Activity</b>	<b>Weight</b>	<b>A x W</b>
<b>MCP FF</b>	0,373	0,780	0,422
<b>MCP MF</b>	0,019*	0,001*	0,020*
<b>MCP HE</b>	0,014*	0,275	0,011*
<b>MMP FF</b>	0,836	0,595	0,845
<b>MMP MF</b>	0,224	0,028*	0,172
<b>MMP HE</b>	0,091	0,554	0,067
<b>IMP FF</b>	0,326	0,760	0,261
<b>IMP MF</b>	0,164	0,013*	0,106
<b>IMP HE</b>	0,658	0,645	0,675

*Table 2: P values for the comparison between initial and final plantar pressure data.*

### CONCLUSIONS

In only 10 days of wearing, differences in insole thickness as well as in plantar pressures were observed. Activity and weight showed to have a significant effect on these changes. Consequently it should be possible to optimize insole material properties according to these variables.



## EFFECTIVENESS OF GAIT IN CP-CHILDREN – A PILOT INVESTIGATION

Kerstin Bosch PhD, Juliane Wühr PhD, Ulrich Hafkemeyer MD

Gait Lab, SPZ Westmuensterland, Children's Clinic, St.-Vincenz-Hospital, Coesfeld, Germany

### INTRODUCTION

Children suffering from cerebral palsy (CP) show a wide variety of abnormal movement patterns. This results in an increase of muscle work, which is ineffective (Brunner, 2010) and rises energy expenditure due to abnormal joint angles (Rose, 1990). By implication the energy consumption decreases if joint angles improve (Brunner, 2010).

A missing initial heel contact during walking in CP patients is one example of atypical joint angles and ineffective muscle work.

Different surgical and conservative intervention strategies are used to achieve an improvement in gait effectiveness. Conservative treatments such as orthotic devices can provide substantial gait improvements.

The aim of this pilot investigation was to verify whether a dynamic lower leg orthosis (LLO) leads to an initial heel contact in CP children who normally show an initial forefoot contact or foot flat.

### MATERIAL AND METHOD

Dynamic foot pressure measurements were obtained in 54 CP-children (age: 4.0 to 17.7 yrs) with GMFCS-level I and II.

Patients walked across two pressure distribution platforms which were embedded in a walkway at self selected speed. Two conditions were investigated, barefoot walking and walking with a dynamic LLO (Fig. 1). The sensor area was approximately 3 m long (100 Hz; 1.4 sensors/cm<sup>2</sup>).

At least 5 left and 5 right foot measurements were analysed at each condition. Dynamic LLOs were individually constructed for each patient and patients wore their own shoes during measurement.

A descriptive statistical analysis was conducted.



Figure 1: Dynamic lower leg orthosis in prepeg-technique with a carbon spring (Hafkemeyer, 2010) manually constructed for each patient.

### RESULTS

All 54 patients showed an initial forefoot contact or foot flat in barefoot walking. While wearing a dynamic LLO 80% (n=43) showed an initial heel contact. A total of 17% (n=9) still performed an initial forefoot contact or foot flat with a dynamic LLO.

Initial contacts of 4% (n=2) showed a wide variety and could not clearly be assigned.

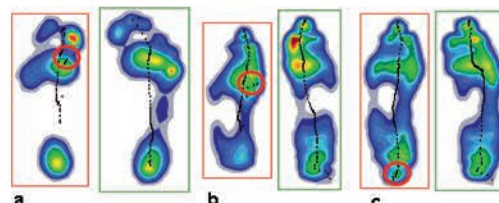


Figure 2: Exemplary pressure pattern of barefoot (a), shod (b) and shod with dynamic LLO (c) – initial contacts marked red.

### DISCUSSION AND CONCLUSION

A dynamic LLO can provide substantial gait improvements like an initial heel contact in CP children. The initial heel contact is an essential approach towards normal gait. A decrease in energy expenditure can be expected in patients showing an initial heel (Brunner 2010).

Future research is planned to investigate the pressure pattern with a dynamic LLO in different shoes during walking by means of pressure distribution insoles.

A 3D gait analysis would also provide information to joint angles and moments to evaluate the effectiveness of a dynamic LLO also on the "whole body".

### REFERENCES

- Brunner *et al*, Orthopaede 39: 15-22. 2010.
- Hafkemeyer *et al*, MOT 6: 57-61. 2010
- Rose *et al*, Dev Med Child Neurol 32: 333-340. 1990.

## DIFFERENT PLANTAR PRESSURE DISTRIBUTION IMAGES IN CHILDREN WITH CEREBRAL PALSY

Alexander A. Patlatov, Vadim N. Tartakovskiy (2), Tatiana L. Tsvetkova (2)

1. The Turner Scientific and Research Institute for Children's Orthopaedics, St.-Petersburg, Russia
2. novel SPb, St.-Petersburg, Russia

### INTRODUCTION

Cerebral palsy (CP) is characterized with gait disorders reflecting the damaged areas of brain. Spastic CP occurs in 80% of all cases (Stanely F. et al., 2000). The aim of this study is to find the specific features of plantar pressure distribution images and to assess the corresponding parameters in children with CP.

### METHODS

18 children (11m/7f), aged 3-16 years ( $7.5 \pm 3.9$ ), diagnosed with spastic CP, were examined. Plantar pressure measurements were performed with emed-AT 25 system (novel, Munich, Germany). Severe gait disorders caused many attempts for children to go across the platform. Two or three steps were registered. Steps extraction procedure was used. Peak pressure (PP), force-time integral (FTI), contact area (CA), contact time (CT) in ms and in % of roll over process (%ROP), begin of contact (BC) in %ROP, and end of contact (EC) in %ROP were calculated for the total foot (TF), hindfoot (HF), midfoot (MF), forefoot (FF), and toes (T) in concert with arch index (AI) for each subject. A comparison of plantar pressure distribution parameters in CP children and in healthy children of the same age (Müller S. et al., 2012) was performed.

### RESULTS AND DISCUSSION

Each patient had a specific plantar pressure distribution image in dependence on the degree of deficiency. The results are referred to the feet (36 feet) because of the presence of both bilateral and unilateral hemiparesis and the loading asymmetry. The results of parameters comparison for children with CP and healthy children are given in table 1.

Table 1. Significantly increased / decreased / nonsignificant difference / undefined parameters (number of feet).

	TF	HF	MF	FF
PP		-/28/2/6	4/18/12/2	4/28/4/-
FTI	26/1/9/-	14/11/5/6	28/2/4/2	19/7/10/-
CA	5/14/17/-			
AI	26/-/4/6			

Time parameters are given in table 2.

Table.2. Time parameters.

	HF	MF	FF	T
CT(p)	60,9 $\pm$ 15,9	67,0 $\pm$ 12,7	86,4 $\pm$ 9,6	88,2 $\pm$ 17,2
BC	2,8 $\pm$ ,2	5,8 $\pm$ 5,4	5,0 $\pm$ 7,8	11,7 $\pm$ 17,2
EC	63,7 $\pm$ 14,0	72,8 $\pm$ 11,1	91,4 $\pm$ 5,1	99,9 $\pm$ 0,9

CT for TF was equal to (1683 $\pm$ 968) ms. Gait line was characterized with V-form with many loops and was shifted in the midfoot-forefoot-toes areas.

All examined patients have typical for CP foot deformities, affecting the plantar pressure distribution pattern. Decreasing of peak pressure can be explained with redistribution of loading between hindfoot and forefoot with toes during gait. Increased force-time integral is defined with increased contact time beneath the foot. Planovalgus foot deformity results in the increased arch index and force-time integral beneath the midfoot. However, the patients with severe deformities have the hope to walk better after the treatment.

### CONCLUSION

The specific features of plantar pressure patterns in children with CP in comparison with healthy children are the following.

- Peak pressure is significantly decreased (especially beneath the hindfoot and forefoot)
- Force-time integral (especially beneath the midfoot) and arch index are significantly increased
- No difference in contact area was found
- Contact time is significantly increased, the forefoot and toes areas are loaded during 100% of roll over process
- The beginning of contact occurred beneath the forefoot and toes

Therefore pedography is a powerful tool for children with cerebral palsy examination for early revealing of biomechanical impairments allowing starting the well-timed treatment to improve the support ability of extremity.

### REFERENCES

- Müller S. et al. Gait&Posture 35(3): 389-94, 2012.  
 Stanely F. et al. Cerebral Palsies: Epidemiology and Causal Pathways. London, UK:MacKeith Press; 2000.

## DO SIGNIFICANT CHANGES IN FOOT GEOMETRY TAKE PLACE IN MULTIPLE SCLEROSIS PATIENTS WITH DIFFERENT NEUROLOGICAL STATUS?

Tatiana L. Tsvetkova (1), Igor D. Stolyarov (2), Andrey M. Petrov (2), Alexander G. Ilves (2), Lidia N. Prakhova (2), Irina G. Nikiforova (2), Viatcheslav V. Lebedev (3)

1. novel SPb, St.-Petersburg, Russia
2. Institute of Human Brain RAS, St.-Petersburg, Russia
3. novel, Munich, Germany

### INTRODUCTION

Knowledge of foot parameters is important to select the shoes which fit properly especially in presence of multiple sclerosis (MS). Complications of spasticity (reported in 84% of MS population) include the development of pes cavus and toes deformities (claw and hammer toes) (Rivera-Dominquez, 1979) influencing on plantar pressure distribution and the foot length and other geometric parameters of the foot during gait. Foot length and width differ for males and females and depend on the age (Gangming Luo, 2009). The aim of this study was to assess the geometric parameters in MS patients with different neurological status as well as for males and females and different age groups using the plantar pressure distribution images.

### METHODS

106 patients (33m/73f), diagnosed with relapsing-remitting MS according to McDonald's criteria, were examined. Neurological status of examined patients was characterized with Expanded Disability Status Scale (EDSS), degree of spasticity – with Ashworth scale. Step1: males and females were divided into 2 groups (M1 and M2, F1 and F2) in relation to estimated EDSS: EDSS [1.0-4.5] (fully ambulatory) and EDSS  $\geq 5.0$  (with impairments to ambulation). Step 2: division of males and females into 2 groups (MA1 and MA2, FA1 and FA2) in relation to age:  $\leq 39$  and  $\geq 40$  (Wen-Bing Horng, 2001). Plantar pressure measurements were performed with emed-AT 25 system (novel, Munich, Germany). Five dynamic records of each foot were made with first step protocol. Arch index (AI), Foot length (FL), Foot width (instep) (FWI), Foot width (narrowest) (FWN), Forefoot width (FFW), Heel width (HW), Instep width (IW), angles, and coefficients were calculated for each subject and for all groups. ANOVA was used for the intergroup comparison (a significance level  $< 0.001$ ).

### RESULTS AND DISCUSSION

M1 vs. M2: decreased AI ( $0.23 \pm 0.07$  vs.  $0.18 \pm 0.08$ ), and Midfoot and forefoot coefficient (MFFC) ( $0.34 \pm 0.15$  vs.  $0.25 \pm 0.09$ ).

F1 vs. F2: decreased AI ( $0.21 \pm 0.07$  vs.  $0.17 \pm 0.08$ ), FWI ( $3.6 \pm 1.1$  vs.  $2.9 \pm 1.2$ ), FWN ( $2.5 \pm 1.0$  vs.  $1.9 \pm 1.2$ ), MFFC ( $0.31 \pm 0.11$  vs.  $0.23 \pm 0.14$ ); increased IW ( $4.0 \pm 0.8$  vs.  $4.7 \pm 0.7$ ) and FL ( $24.5 \pm 1.2$  vs.  $25.3 \pm 1.4$ ).

MA1 vs. MA2: decreased AI ( $0.24 \pm 0.07$  vs.  $0.21 \pm 0.06$ ), FWI ( $4.0 \pm 1.3$  vs.  $3.3 \pm 1.1$ ), FWN ( $2.9 \pm 1.1$  vs.  $2.3 \pm 0.9$ ), MW ( $3.5 \pm 1.4$  vs.  $2.8 \pm 1.0$ ), MFFC ( $0.36 \pm 0.16$  vs.  $0.27 \pm 0.10$ ), increased FFW ( $9.9 \pm 0.7$  vs.  $10.2 \pm 0.7$ ), IW ( $4.2 \pm 1.2$  vs.  $4.9 \pm 0.6$ ),

FA1 vs. FA2: decreased FL ( $24.7 \pm 1.0$  vs.  $24.4 \pm 1.3$ ), increased HW ( $5.4 \pm 0.5$  vs.  $5.6 \pm 0.5$ ).

M2 vs. MA2: no significantly different parameters were found.

F2 vs. FA2: decreased AI, FWI, FWN, MW, MFFC and increased IW, FL.

Foot length and foot width have a tendency to be increased with age, when ligaments, tendons, and muscles become thinner and weaken and do not hold the bones and joints together, in concert with flattening of the foot arch. Pes cavus and other toe deformities development with MS progress and muscle imbalance in the foot cause the shortened foot length, decreased arch index, foot width (instep and narrowest) and increased instep width. Foot drop that affects walking with a difficulty to properly lift the front part of the foot can cause the “increased” foot length in walking.

### CONCLUSION

Expected age changes (increased forefoot width) were found for males. The most significant changes were found due to presence and development of high arch. MS patients need to pay more attention to their shoe regarding the proper size, width, and shape. Shoe gear modification and the custom orthotics can be used in special cases to control the abnormal biomechanics and to prevent pain and instability.

### REFERENCES

- Gangming Luo et al. JAPMA. 99(5):383-90, 2009. 2.  
Rivera-Dominquez M. et al. Paraplegia. 16(4):375-82, 1979.  
Wen-Bing Horng et al. TJSE. 4(3):183-92, 2001.



## GLUCOCORTICOID MEDICATION REDUCES METACARPOPHALANGEAL JOINT STIFFNESS IN PATIENTS AFFECTED BY RHEUMATOID ARTHRITIS

William R. Taylor (1), Annika Fröhlich (1), Frank Buttgereit (2), Rainald M. Ehrig (3), Tom Witaschek (4), Georg N. Duda (1)

1. Julius Wolff Institute, Charité - Universitätsmedizin, Berlin, Germany
2. Department of Rheumatology and Clinical Immunology, Charité - Universitätsmedizin Berlin
3. Zuse Institute Berlin (ZIB), Berlin, Germany
4. Towicon, Bad Wildungen, Germany

### INTRODUCTION

Rheumatoid arthritis (RA) is one of the single most health-related quality-of-life reducing chronic diseases (Strand *et al.* 2010). Unspecific symptoms such as pain, joint swelling and tenderness, especially in the most frequently affected metacarpophalangeal (MCP) joint, makes the quantification, early identification and monitoring of rheumatoid arthritis difficult, which results in generally subjective diagnoses. The aim of this study was to assess whether objective biomechanical parameters such as joint stiffness and range of motion (RoM) are sufficiently reliable for the subject specific determination of disease status and progression and if such measurements are affected by therapy in RA patients.

### METHODS

A device for determining passive stiffness and energy dissipation of the MCP joint against an externally applied torque during flexion and extension was constructed (Figure 1) and tested for reliability ( $n=13$  healthy subjects, 6 repetitions). Forty healthy subjects were then classified into four cohorts (males, females, young (20-35years) and old (45-80years)) and tested to investigate the influence of age and gender on MCP joint stiffness and RoM. 13 female patients suffering from RA were then examined both pre- and ~2hours post-glucocorticoid (prednisolone) medication.

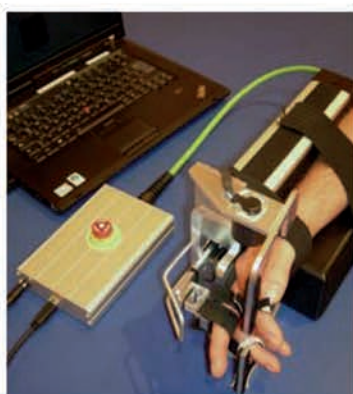


Figure 1: MCP joint stiffness testing device, together with safety shut-off button and notebook for recording and analysing data.

### RESULTS

Tests in healthy subjects demonstrated excellent reliability ICC(3,1) for both joint stiffness ( $0.83 \pm 0.07$ ) and dissipated energy ( $0.82 \pm 0.04$ ). Males and elderly had a higher passive joint stiffness and lower RoM than women and younger subjects. The joint stiffness of patients was higher than healthy subjects, particularly at  $60^\circ$  flexion ( $p<0.05$ ) (Figure 2). Medication reduced the mean joint stiffness in RA patients from  $4.9\text{Nm}/^\circ$  pre-medication to  $3.6\text{Nm}/^\circ$  post-medication ( $p<0.05$ ), which approached the values of healthy subjects.

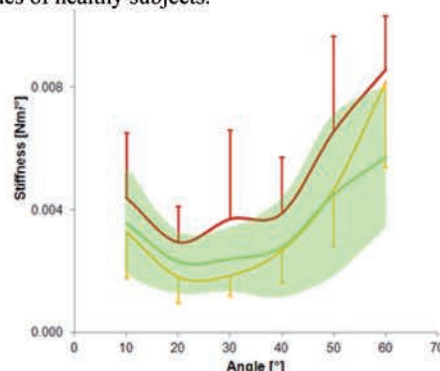


Figure 2: Comparison of female RA patients at pre (red)- and post (orange)-medication time points against healthy age-matched female controls (light green, mean  $\pm$  SD)

### DISCUSSION

Despite the large variability in joint stiffness, range of motion and energy dissipation across cohorts, this study demonstrates the high reliability of quantifying functional outcome in individuals. This rapid and non-invasive approach now opens perspectives for early quantification and monitoring of RA disease status and progression, including the evaluation of morning stiffness (Strand *et al.* 2010), and objective differentiation between different therapy strategies by means of functional outcome in vivo.

### REFERENCES

Strand *et al.*, Clin Exper Rheumatol 28:S32-40, 2010.



## CLINICAL RELEVANCE OF ANATOMY-BASED PLANTAR PRESSURE ANALYSIS IN CLUBFOOT.

Julie Stebbins (1), Claudia Giacomozzi (2)

1. Nuffield Orthopaedic Centre, Oxford, UK
2. Dept. Of Technology and Health, Italian National Institute of Health (ISS), Rome, Italy

### INTRODUCTION

It is often clinically important to report plantar pressure variables within sub-areas of the foot. Traditional masks which divide the foot based on pre-defined criteria, such as percentage length and width of the foot, have been shown to be adequate when measuring feet without any anatomical deformity. However, it produces inaccurate results when foot deformity is present. We have previously reported a method for sub-dividing the plantar pressure footprint based on projecting motion capture markers directly onto the footprint at the time corresponding to mid-stance (Giacomozzi 2000; Stebbins 2005). While this method has proven reliable when measuring non-pathological feet, it is yet to be tested in the presence of foot deformity. The aim of this study is to determine the applicability of the marker-based method in clubfoot, compared to traditional masking; and compared to healthy subjects.

### MATERIALS AND METHODS

In 2010, the authors presented the results of a validation study on the anatomical (marker-based) masking of plantar pressure data, conducted on 100 footprints from young healthy volunteers (20 children, 6M and 14F, age 6–16 years) (Giacomozzi, 2010). The same methodology (markers applied to both feet according to the Oxford Foot Model), equipment (Vicon MX system and EMED-M platform) and acquisition protocol (barefoot level walking at self-selected speed), were applied to a group of 20 children with clubfoot (15M and 5F, age 6–16 years), including a total of 51 footprints. 3D trajectories of relevant foot markers were then projected onto the dynamic footprints at mid-stance, and were used to identify medial and lateral hindfoot, midfoot, and medial and lateral forefoot areas. Geometrical selection was then performed for comparison, based on the bisecting line of the footprint and on the default EMED software masks for the 5 foot regions. For the two selection methods, absolute differences of relevant parameters (Table 1) were analysed and compared with the corresponding differences found for non-pathological footprints.

### RESULTS

Differences between the two selection methods were up to 40% in the clubfoot population (Table 1). This compares to differences less than 5% for the healthy population. Almost all differences in clubfoot were statistically higher than in healthy footprints using a t-test, except for PP and PTI in midfoot, and PP in medial hindfoot and lateral forefoot.

Table 1 % difference in mean (sd) between masking methods. PP=peak pressure; PTI=Pressure Time Integral; MF=Max Force; FTI=Force Time Integral; CA=Contact Area

	PP	PTI	MF	FTI	CA
MEDIAL HINDFOOT	1.0 (2.3)	1.9 (7.0)	11.3 (9.0)	5.2 (4.3)	4.8 (3.3)
LATERAL HINDFOOT	11.2 (19.6)	4.6 (7.1)	11.0 (7.1)	4.9 (3.4)	4.3 (2.7)
MIDFOOT	6.0 (5.0)	5.7 (3.7)	12.0 (4.7)	7.4 (3.8)	11.5 (3.2)
MEDIAL FOREFOOT	31.8 (23.1)	27.7 (25.8)	40.4 (20.5)	22.8 (12.9)	19.7 (7.8)
LATERAL FOREFOOT	3.9 (7.5)	4.5 (5.6)	8.0 (6.7)	6.0 (4.4)	10.2 (5.3)

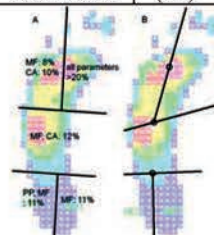


Figure 1: example of geometrical (A) and anatomical (B) selection of the 5 areas. Footprint A shows peak difference in the two methods

### DISCUSSION AND CONCLUSIONS

The proposed anatomical masking allows reliable and accurate pressure measurements in clubfoot, while remaining automatic. It also allows the construction of a reference, comparison database, composed of healthy footprints; a widely accepted practice in other aspects of gait analysis.

### REFERENCES

- Giacomozzi *et al*, MBEC, 38(2):156-63, 2000.  
 Giacomozzi *et al*, ESM2010 workshop on "3D motion capture systems and pedography".  
 Stebbins *et al*, G&P, 22(4):372-6, 2005.

## DEFICITS IN FORWARD PROPULSION REMAIN 2-5 YEARS AFTER UNILATERAL ACHILLES TENDON RUPTURE

Alison N. Agres (1), William R. Taylor (1), Tobias Gehlen (2), Georg N. Duda (1), Sebastian Manegold (2)

1. Julius Wolff Institute, Charité - Universitätsmedizin Berlin, Germany
2. Center for Musculoskeletal Surgery, Charité - Universitätsmedizin Berlin, Germany

### INTRODUCTION

Achilles tendon rupture is a prevalent clinical problem; however, follow-up clinical examinations lack objectivity for assessing ankle joint function and the biomechanical status of the tendon tissues, where regeneration is load-dependent. This unilateral injury is thought to lead to asymmetry during high-impact exercises up to two years after surgery (Olsson et al, 2011), but it remains unknown whether these asymmetries are present during daily, low-impact functional activities, such as ambulatory gait.

The Achilles tendon is primarily engaged in both forward and vertical propulsion of the body. Parameters of dynamic loading could therefore be measured and used as a clinical tool for the objective assessment of healing status. The aim of this study was thus to determine the lasting effect of Achilles rupture on symmetry during walking.

### METHODS

Twelve subjects (3 female, 9 male) were recruited 2-5 years ( $3.0 \pm 0.65$ ) following minimally invasive surgical repair (Amlang et al, 2006) of an Achilles tendon rupture performed by the same surgeon (SM). Achilles Tendon Rupture Scores (ATRS) and Trillat Scores were assessed to provide a clinical evaluation of ankle joint and tendon status. Subjects then walked barefoot along a 10m marked walkway at a self-selected speed. Ground reaction forces (GRFs) were recorded using two embedded AMTI force plates (AMTI, Watertown, USA) at 960 Hz. To avoid any possible velocity bias, trials were selected for analysis when both feet consecutively and cleanly hit each force plate.

All GRF data were filtered (two-way Butterworth, 4<sup>th</sup> order, cutoff 50 Hz) within the MATLAB suite (Mathworks, MA, USA). After filtering, the following parameters were calculated in the vertical and anterior-posterior directions: first (landing) and second peak forces (propulsion), rates of loading and propulsion, and propulsive impulses.

### RESULTS

High subject satisfaction (Trillat  $1.83 \pm 0.7$ , ATRS  $87.4 \pm 0.7$ ) was recorded. Comparison of the injured and non-injured sides revealed significant

differences in loading rate, the second peak force, propulsion rate and the propulsive impulse in the anterior-posterior directions (Table 1). Other than the overall impulse, no significant differences were found in the vertical GRF data.

Parameter	Vertical GRF		Ant-post GRF	
	Injured	Non-injured	Injured	Non-injured
<b>Loading rate (BW/s)</b>	7.09 $\pm 0.9$	7.10 $\pm 1.1$	<b>1.81 <math>\pm</math> 0.7</b>	<b>2.16 <math>\pm</math> 1.1</b>
<b>Peak propulsive force (BW)</b>	1.12 $\pm 0.1$	1.12 $\pm 0.1$	<b>0.17 <math>\pm</math> 0.03</b>	<b>0.19 <math>\pm</math> 0.04</b>
<b>Propulsion rate (BW/s)</b>	6.90 $\pm 1.1$	6.88 $\pm 1.3$	<b>2.0 <math>\pm</math> 0.5</b>	<b>2.2 <math>\pm</math> 0.6</b>
<b>Overall Impulse (BW-s)</b>	<b>0.527 <math>\pm</math> 0.03</b>	<b>0.534 <math>\pm</math> 0.04</b>		
<b>Propulsive impulse (BW-s)</b>			<b>0.024 <math>\pm</math> 0.004</b>	<b>0.027 <math>\pm</math> 0.004</b>

Table 1: Ground reaction force (GRF) measures in both the vertical and anterior-posterior directions. (BW = force normalized to body weight. Bold text indicates a significant difference between injured and non-injured sides with  $p < 0.005$ , paired-sample T-test)

### DISCUSSION

Lasting asymmetries in forward propulsion were found during walking in all subjects following a previous Achilles tendon rupture, even though clinical scores reported satisfactory outcomes. The results of this study suggest that the local tissues on both the injured and non-injured sides are subjected to modified loading conditions during common activities of daily living, possibly leading to localized load-dependent tissue adaptation. Whether the observed altered forward propulsion at the ankle joint leads to a heightened risk of joint degeneration remains to be investigated.

### REFERENCES

- Amlang *et al*, Oper Orthop Traumatol 18: 287-99, 2006.  
 Olsson *et al*, Knee Surg Sports Traumatol Arthrosc 19:1385-93, 2011.



# INVESTIGATION OF HUMAN-STRUCTURE DYNAMIC INTERACTION USING BIOMECHANICAL MODEL

Hiep V. Dang, Stana Živanović

School of Engineering, University of Warwick, United Kingdom

## INTRODUCTION

In structural dynamics the Human-Structure Dynamic Interaction (HSDI) is a phenomenon which occurs when people who dynamically excite the structure are at the same time perceiving the vibrations induced and reacting to them. The focus of this research is to quantify alterations of pedestrian's walking forces during HSDI.

The final aim is to establish a comprehensive numerical model of HSDI that can help structural engineers in making accurate vibration predictions for structures exposed to walking-induced loads.

## METHODS

Conventional models of dynamic forces induced by walking activity assume the walking over rigid surfaces. This assumption makes the currently available models unsuitable for vibration analysis in presence of HSDI. To address this shortcoming, the future models must be based on the underlying mechanics of human walking. Based on a review of existing walking models from the biomechanics research field, the Spring Mass with Roller Feet model (SMRF) by Whittington and Thelen (2009) was found to be most promising. The model consists of a body mass  $m$  on top of massless legs (modelled as two identical springs) with roller feet (having shape of a half circle). The model and the simulation of Ground Reaction Forces (GRFs) it can generate over rigid ground are illustrated in Figure 1. In comparison to experimental data, the simulation result of SMRF model correlates quite well in both time and frequency domains.

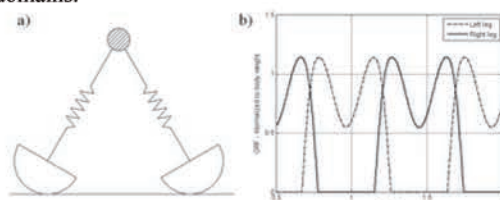


Figure 1: a) SMRF model, b) GRFs over rigid ground

To incorporate the effect of HSDI into the model, a new variable in form of acceleration of the moving footbridge structure (Bocian et al, 2011) is introduced in the equations of motion of SMRF model. This acceleration is in first instant modelled as

a sine function weighted by the structural mode shape to account for vibration level to which the SMRF model is exposed while crossing the structure.

## RESULTS

The simulation result for the vertical movement of Body Centre of Mass (BCoM) and the new variable of structure's response are shown in Figure 2.

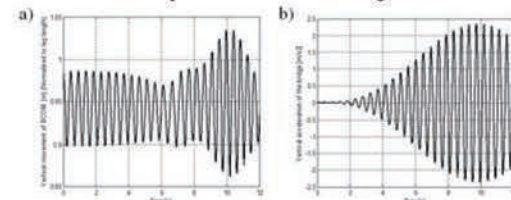


Figure 2: a) Vertical movement of BCoM, b) Structure's response

## DISCUSSION

Figure 2 shows that in the initial stage of bridge crossing (when the structural response is relatively small) the effect of HSDI on SMRF model is almost non-existent, and the movement of the centre of mass is similar to that for walking over a rigid surface. As the response of the structure builds up, the BCoM starts fluctuating more. This is believed to occur due to the pedestrian adjusting their gait to the ground movement.

Next stage of the research is experimental verifications of the model in well controlled laboratory conditions and with the use of a motion capture system to monitor both human and structural movement. In addition, the current SMRF model is being developed to create an active feedback loop between the force and the structural response: as the SMRF model moves along the structure it generates GRFs, this force is then input in the equation of motion for the structure to get the vibration response, i.e. acceleration, which in turn influences the generated force.

## REFERENCES

- Bocian, M. *et al*, EUROODYN, 2011
- Whittington, B.R., and Thelen, D.G., *Journal of Biomechanical Engineering* 131(1), 2009.



## A DISCRIMINANT ANALYSIS TO DISTINGUISH PLANUS, RECTUS AND CAVUS FOOT TYPES

Howard J Hillstrom (1,2,3), Jinsup Song (3), Rajshree Mootanah (1,2), Smita Rao (1,4), Andrew P. Kraszewski (1), Jocelyn F. Hafer (1), Sherry Backus (1), Jonathan Deland (1)

1. Hospital for Special Surgery, New York, USA
2. Anglia Ruskin University, Essex, UK
3. Temple University School of Podiatric Medicine, Philadelphia, USA
4. New York University, New York, USA

### INTRODUCTION

Differences in foot structure are postulated to be associated with differences in foot function during static posture or dynamic movement. Many foot pathologies are biomechanical in origin and often associated with planus and cavus foot types (Naudi et al, 2009), while rectus feet have not been directly associated with pathology or injury in the literature. It is not clear why certain foot pathologies are associated with specific foot types or why some individuals with non-rectus foot types are asymptomatic. In order to systematically study foot pathologies, responses to treatment, and methods of prevention, objective measures of foot structure and function that differ between foot types are needed. The purpose of this study was to determine if planus, rectus and cavus foot types could be predicted from objective measures of foot structure and function in asymptomatic individuals.

### METHODS

Sixty-one asymptomatic healthy adults, between 18 and 77 years of age, with no symptoms of pain, pathology or deformity were recruited. Their feet were categorized planus, rectus or cavus foot types, based on their resting calcaneal stance position (RCSP) and forefoot to rearfoot relationship (FF-RF) angles (Root, 1977). Measures of foot structure included malleolar valgus index, MVI (%), and arch height index, AHI (%). Measures of foot function included: plantar loading parameters as measured by an emed-x (Novel, Munich, Germany) plantar pressure measuring device (1.6% full-scale error) (Hillstrom et al, 2008); center of pressure excursion index, CPEI (%) (Song et al., 1996); Peak pressure (PP) and Maximum force (MF); and stance time. Discriminant analysis was conducted with SPSS version 19. Two canonical discriminant functions were formed from linear combinations of 13 structural and functional variables.

### RESULTS AND ANALYSIS

The centroids of the three foot types: (1) planus, (2) rectus, and (3) cavus are shown in Figure 1. Of the 61 subjects 57 cases were complete and entered into analysis (19 planus, 26 rectus, and 12 cavus). There

was a 78.9% correct classification of the originally grouped cases. For those cases included cross validation yielded 52.6% correct classification.

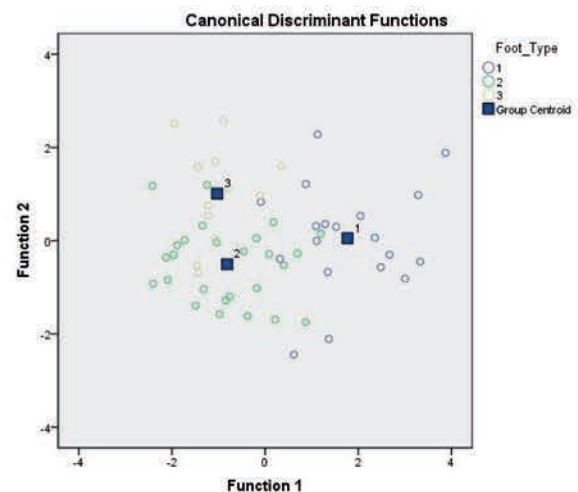


Figure 1: Discriminant Analysis of: (1) planus, (2) rectus, and (3) cavus foot types

### DISCUSSION

Planus, rectus, and cavus foot types were classified by canonical discriminant function based upon a linear combination of 13 measures of foot structure and function with 78.9% accuracy. It should be noted that this data set is comprised of only asymptomatic healthy individuals. The addition of individuals with pathology and more extreme planus and cavus foot types is anticipated to improve classification performance.

### REFERENCES

- Hillstrom et al, ESM, 2008  
 Naudi, Orthop.Traumatol.Surg.Res.2009;95:293-300  
 Root ML, Clinical Biomechanics Corp. 1977  
 Song et al, J.Am.Podiatr.Med.Assoc. 1996; 86: 16-23

### ACKNOWLEDGEMENTS

NIH GRANT 1R03HD053135-01

## INTRAARTICULAR FORCE DISTRIBUTION IN THE FEMOROTIBIAL JOINT IS RELATED TO KNEE ADDUCTION MOMENT AND KNEE FLEXION

Karsten Engel (1), Gert-Peter Brüggemann (1), Kai Heinrich (1), Ingo Volker Rembitzki (1), Christian Liebau (2)

1. Institute of Biomechanics and Orthopaedics, German Sport University Cologne, Germany
2. Asklepios Harzlinik, Bad Harzburg, Germany

### INTRODUCTION AND PURPOSE

Varus malalignment of the knee has been identified as a risk factor for the development and progression of knee osteoarthritis (Brouwer, 2007). Varus malalignment is associated with an increased external adduction moment at the knee during ambulation and the determination of the external adduction moment at the knee is commonly used to predict the biomechanical risk of osteoarthritis (Andriacchi, 1994). It has been speculated that the external adduction moment alters the load distribution between the medial and lateral compartment of the knee. Fantini Pagani et al. (2010) demonstrated that a valgus bracing can modify the resulting net moment of the knee in the frontal plane during daily activities such as walking by applying an external abduction moment. Furthermore the redistribution of the load between the medial and lateral compartments as a result of an external valgus moment to the knee by a valgus knee brace was reported by applying a simple mathematical model (Shelburne et al., 2008). Kutzner et al. (2011) measured a decreased medial compartment forces when applying an external abduction moment by an orthosis measured with an instrumented implant during walking in three patients. The published adduction moments during the gait cycle indicate a possible relationship of the resultant adduction moments and the knee flexion angle and therefore a relation of knee medial compartment loading and knee flexion. No experimental data of pressure distribution within the knee joint compartments of a native joint as a function of the knee adduction moment and knee flexion angle are available.

The purpose of the study is to quantify the intraarticular force distribution in the femorotibial joint in relation to the external adduction moment and the knee flexion angle.

### MATERIALS AND METHODS

A dynamic muscle controlled knee squat was simulated on six fresh-frozen human leg specimens with an upright knee simulator. During knee flexion and extension the femorotibial pressure distribution was measured with two Kneepad S sensors (Novel, Munich). Experimentally an external adduction/abduction moment was applied by a customized orthosis which allowed the application of moments from -5 to 5 Nm. The specimens were amputated at 250 mm

from the knee joint line, the femur was mounted onto a steel cylinder and positioned in the simulator. The extensor muscles and the hamstrings were connected with pneumatics actuators which applied a constant force of up to 100 N in order to counterbalance gravitational forces to the muscles. The patella tendon was enforced by a 15 mm wide polyester band, which was screwed to the patella and proximally connected with a pneumatic actuator (250, 500, 750 N). Additional axial forces of 100 and 250 N were applied to the femur. The motion of the femur and the tibia was measured by a six-camera 3D motion analysis system (Vicon Nexus) operating at 100 fps (bone pins in femur and tibia with retro reflective marker arrays).

### RESULTS

The range of knee flexion during the simulated squat was measured at  $60 \pm 5^\circ$  indicating that the simulation covers the range of knee flexion during daily activities. Medial compartment force was higher than the lateral compartment force for all specimens with neutral or varus knee alignment. With increasing knee flexion the medial compartment force increases. The externally applied moment is strongly related to the relative and absolute medial compartment loading.

### DISCUSSION

Medial compartment joint load is a function of the external adduction moment and knee flexion. With externally applied abduction moments, e.g. by valgus braces, the remaining adduction moment at the knee and therefore the medial compartment load can be reduced. This result and the relationship between medial compartment load and knee flexion offers novel concepts for the development and optimization of technical aids and conservative treatment of the osteoarthritic knee. The findings have relevance for the adjustment of mechanical aids to reduce the intraarticular knee loading at a minimum of patients' compliance.

### REFERENCES

- Andriacchi, Orthop Clin N Am 25, 395-403, 1994.
- Brouwer et al., Arthritis Rheum 56, 1204-1211, 2007.
- Fantini Pagani, et al., Clin. Biomech 25, 70-76, 2010.
- Kutzner et al., J.Biomech 44, 1354-1360, 2011.
- Shelburne et al., Clin. Biomech 23, 814-821, 2008.



## PROGNOSTIC FACTORS IN THE CAUSATION OF RECURRENT PLANTAR ULCERATION IN PATIENTS WITH DIABETES.

Roelof Waaijman (1), Mirjam de Haart (1), Mark L.J. Arts (1), Daan Wever (2), Anke Verlouw (3), Frans Nollet (1), and Sicco A. Bus (1,4)

1. Department of Rehabilitation, Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands
2. Department of Rehabilitation, Medisch Spectrum Twente, Enschede, the Netherlands
3. Department of Rehabilitation, Maxima Medical Centre, Veldhoven, the Netherlands
4. Department of Surgery, Ziekenhuisgroep Twente, Almelo, the Netherlands

### BACKGROUND

Elevated plantar pressure is a risk factor for ulceration in diabetes (Frykberg, 1998). Custom-made footwear is aimed to reduce pressures and is often prescribed to patients at high risk for re-ulceration. Despite this, ulcer recurrence rates are still high, up to 40% annually. Many factors may contribute to this outcome, including biomechanical factors such as barefoot and in-shoe plantar pressure, disease related factors, and behavioral factors, such as adherence to prescribed footwear use and activity level of the patient. Prospective studies that determine the role of all these factors in plantar foot ulceration is non-existent, but important for screening and treatment purposes to reduce risk for ulceration. Therefore, the aim of this study was to assess the predictive value of disease-related, biomechanical, and behavioral factors on plantar foot ulceration in diabetic patients at high risk for foot ulceration.

### METHOD

In a multicenter prospective study design, 171 diabetic patients (141 men, mean age 63.3) with neuropathy, a recently healed plantar foot ulcer, and custom footwear were followed for 18 months or until plantar ulceration. At entry, patient and disease-related factors were assessed. Barefoot peak pressures distal to the heel were measured using the EMED-x system, and in-shoe pressures were measured using Pedar-X. At each 3-month follow-up, visits to the footcare provider, minor lesions, and ulceration as assessed from photographs by a panel of 3 blinded observers was assessed. Adherence to footwear was measured over a 7-day period using shoe worn sensors (@monitor), together with daily step count using an ankle-worn step activity monitor (StepWatch).

Univariate logistic regression ( $P < 0.10$ ) was used to assess independently determinants of ulceration in two separate models: one including parameters at the patient level ( $N=171$ ), and another including parameters at the foot level ( $N=342$ ). Using ANOVA ( $P < 0.05$ ), we compared in-shoe and barefoot pressures between patients who re-ulcerated at the same location and those who did not.

### RESULTS

Significant predictors of ulcer recurrence were: type of footwear (semi-customized,  $OR=0.49$ ), variance in number of daily steps ( $OR$  per 100 steps = 0.98), cumulative months of prior ulceration ( $OR=1.03$ ), minor lesions (presence of major callus, hemorrhage, or blister,  $OR=8.19$ ), barefoot peak pressure ( $OR$  per 50 kPa = 1.11), level of deformity (moderate or severe,  $OR=1.78$ ), and foot amputation ( $OR=2.26$ ). Non-significant predictors were gender, age, ethnicity, social status, education level, diabetes type, diabetes duration, HbA1c, BMI, daily step count, footwear adherence, in-shoe peak pressure, and peripheral arterial disease.

Mean ( $\pm$ SD) barefoot and in-shoe peak pressure at the previous ulcer location was significantly higher in those patients who re-ulcerated at that location compared to those who did not (in-shoe:  $172 \pm 96$  vs.  $211 \pm 98$  kPa, barefoot:  $671 \pm 392$  vs.  $865 \pm 375$  kPa).

### DISCUSSION

Several significant disease-related predictive factors found were also identified in previous studies (Boyko et al, 1999). Some predictive factors are unalterable, such as elevated barefoot pressures, severity of deformity and cumulative months of previous ulcers, whereas others are alterable, such as type of footwear, variance in number of daily steps and minor lesions. In-shoe plantar pressure did not prove predictive of ulceration, although those who re-ulcerated had significantly higher in-shoe pressures.

This study shows which risk factors should be screened for in this high-risk group of patients. For the prevention of ulcer recurrence in diabetic neuropathy, the focus should be on managing alterable factors such as behavior of the patient and certainly minimizing minor lesions and on reducing in-shoe peak pressure at the previous ulcer location.

### REFERENCES

- Frykberg *et al*, Diabetes care 21: 1714-1719, 1998.  
Boyko *et al*, Diabetes Care 22: 1036-1042, 1999.

## CHANGES IN COP DISPLACEMENT WITH THE USE OF A FOOT DROP STIMULATOR IN INDIVIDUALS WITH STROKE

Karen J. Nolan, PhD (1,2), Mathew Yarossi, MS (1,2)

1. Kessler Foundation Research Center, Human Performance and Engineering Laboratory, West Orange, NJ, USA, [www.kesslerfoundation.org](http://www.kesslerfoundation.org).
2. UMDNJ – New Jersey Medical School, Department of Physical Medicine & Rehabilitation and Graduate School of Biomedical Sciences, Newark, NJ, USA

### BACKGROUND AND PURPOSE

Foot drop secondary to stroke causes decreased mobility and functional disturbances in healthy walking patterns. Emerging research suggests that FES (functional electrical stimulation) could serve as a principal substrate for facilitating motor recovery after stroke. Surface FES can be applied to the peroneal nerve as a rehabilitation intervention for foot drop to provide active dorsiflexion (lift the foot) in weak or paralyzed muscles. Precise changes in the center of pressure (COP) during gait can provide information about underlying control mechanisms of the neuromuscular system and the efficacy of a foot drop stimulator. Therefore, the purpose of this investigation was to evaluate changes in COP displacement in individuals with stroke with and without the use of a drop foot stimulator and healthy adults.

### METHODS

**SUBJECTS:** Eleven individuals diagnosed with foot drop secondary to stroke (age  $60 \pm 8$  y, height  $1.78 \pm 0.11$  m, mass  $85 \pm 11$  kg,  $112 \pm 76$  months post stroke) currently using a commercially available foot drop stimulator (FDS) for ambulation (Walkaide, Innovative Neurotronics, Inc., Austin, TX, USA) and eleven healthy controls (age  $54 \pm 15$  y, height  $1.67 \pm 0.10$  m, mass  $68 \pm 13$  kg) were recruited for participation.

**PROCEDURES:** Wireless plantar pressure data was collected at 100 Hz using the pedar®-X Expert System (Novel Electronics Inc., St Paul, MN, USA) bilaterally during walking. Individuals with stroke performed 2 five meter walks with and without their FDS at a self selected speed on level ground. The healthy control (HC) group performed a two-minute walk at a self-selected pace and data from the first 18 seconds of the walking test was used for analysis. The main outcome measures were: 1) anterior/posterior (A/P) (% insole length) and medial/lateral (M/L) (% insole width) center of pressure (COP) position at initial contact, and toe off; 2) A/P COP net displacement (% insole length) during stance, initial double support (IDS), single support (SS), and terminal double support (TDS); and 3) self-selected walking speed.

**ANALYSIS:** Data was exported as A/P and M/L position and displacement variables, and calculated in custom Matlab programs.

### RESULTS

A/P maximum COP excursion on the affected limb increased 8% ( $54.1 \pm 11.9$  with;  $46.0 \pm 10.7$  without) during stance in the stroke group with FDS ( $p=0.001$ ) and  $63.8 \pm 0.63$  in the HC group. COP at initial contact was 6% more posterior ( $26.7 \pm 17.8$  with;  $33.8 \pm 18.9$  without) with FDS ( $p=0.043$ ) and  $13.4 \pm 1.1$  in the HC group. M/L mean ( $58.1 \pm 7.7$  with;  $61.4 \pm 7.6$  without;  $p=0.025$ ), maximum ( $67.3 \pm 5.8$  with;  $71.6 \pm 6.3$  without;  $p=0.014$ ) and minimum ( $42.2 \pm 14.0$  with;  $49.2 \pm 23.2$ ;  $p=0.027$ ) COP position during stance all significantly decreased with the FDS on the affected limb in the stroke group. A/P net displacement on the affected limb with FDS increased during stance ( $46.4 \pm 18.1$  with;  $38.4 \pm 18.1$  without;  $p=0.039$ ) and single support ( $15.8 \pm 14.9$  with;  $13.6 \pm 14.4$  without;  $p=0.019$ ). Walking speed (m/s) was  $0.60 \pm 0.25$  with;  $0.62 \pm 0.28$  without; and  $1.27 \pm 0.19$  HC.

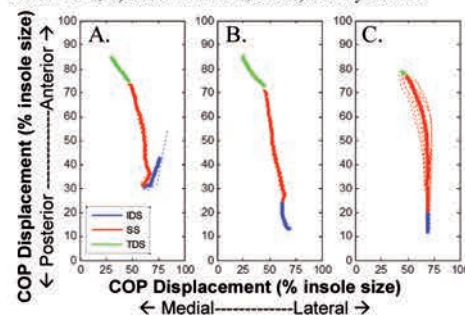
### DISCUSSION AND CONCLUSION

Individuals with stroke using a FDS contacted the ground more posterior at footstrike and utilized more of the A/P plantar surface of the foot on the affected limb during stance. With the FDS there is also a shift in COP towards the medial side possibly indicating an improvement in equinovarus gait where there is a tendency to load the lateral foot throughout stance. For individuals with stroke a FDS can improve displacement of the COP which indicates improved forward progression and stability during stance.

### REFERENCES

1. Mizelle, C., et al. *Gait & Posture* 24:356-363, 2006
2. Nardone, A., et al. *Gait & Posture* 30:5-10, 2009

Figure 1: COP Displacement, one representative individual: A) Stroke without FDS; B) Stroke with FDS; and C) Healthy control.





## FROM 2006 TO 2012: RELEVANT STEPS AND CHANGES IN PLANTAR PRESSURE MEASUREMENT.

Claudia Giacomozzi (1)

1. Dept. Of Technology and Health, Italian National Institute of Health (ISS), Rome, Italy

### INTRODUCTION

Plantar pressure measurement deserves a prominent place among the methodologies for investigating foot biomechanics, but it is mandatory for the measurements to be reliable, accurate, and comparable. The first step to reach the goal is of course the standardization of methodology and instruments for technical assessment; however, it might not be sufficient without the proper cultural background and the perception of such a need by all users and manufacturers. This contribution summarizes the main activities and changes conducted, occurred or “perceived” since the ISS first proposal in 2006, as well as the main ongoing or future actions.

### PRELIMINARY ACTIONS

In 2006 ISS validated its own methodology and instruments for the assessment of the technical performance of pressure measurement devices (PMD) arranged in the form of rigid matrices for level barefoot gait analysis. Preliminary assessments and comparisons were conducted on some commercial products (Giacomozzi, G&P 2010). Proposals were successively disseminated through publications and workshops aimed at reaching consensus at least with respect to Medical PMDs, i.e. those devices that, being used on patients to quantitatively support diagnosis and therapy, are to be classified as Medical Devices with measuring function (Giacomozzi, Ann Ist Sup San, 2010). Efforts were addressed to: i) make the users aware of the need to periodically assess PMD performance on-site; ii) convince the manufacturers to collaborate and improve in-factory and on-site technical assessment; iii) give technical support to both users and manufacturers with independent assessment at ISS, free on-site workshops or advices, technical specs for simple testing tools; iv) bring the attention on Consensus to a higher level in the scientific community: in 2010 an initiative was launched within the i-FAB-PG, i.e. the Pedobarographic Group of the International Foot and Ankle Biomechanics community; v) alert the international organizations for Standards on the lack of proper Technical Standards.

### STATE OF THE ART

The Consensus initiative within the i-FAB-PG was successfully closed in April 2012, and the official document will be published in June 2012. Extremely important and accurate with respect to PMD assessment in the presence of uniformly distributed

load, the document needs however further improvement to properly infer on PMD performance in the presence of concentrated load.

Positive feedback came from some manufacturers, e.g.: AmCube delivered a new PMD and asked ISS for a new assessment to be done in the next months; Tomorrow Options officially asked ISS to test their WalkinSense wearable system by using the same methodology and tools proposed for PMDs, and implemented both a standardized assessment procedure in-factory and a simple on-site testing tool (only suitable for isolated sensors); ViTrak System is going to launch a new PMD in 2013 – declared as compliant to the i-FAB-PG recommendations - and is in contact with ISS for the technical specs of the ISS Portable testing system. Specs of this tool had also been delivered to two interested users in Italy and one Company in Europe for investigating its marketing.

Awareness has grown among the users through the years, and several issues on appropriateness of PMDs have been shared and discussed through the ISS web forum.

As for Technical Standards, a dedicated working group has been set up in 2012 within the Italian Electro-Technical Committee: under the guide of ISS, the group is preparing a Technical Standard for in-factory and periodic assessment of Medical PMDs.

### ONGOING AND FUTURE ACTIONS

Starting from the i-FAB Consensus, ISS is launching a world-wide activity to improve and complete the document and to prepare Official Guidelines with the agreement of as many Clinicians, Researchers and Scientific Societies as possible.

The preliminary assessment ISS conducted on wearable systems highlighted the urgent need to properly adapt methodology and tools to assess in-shoe systems too: it is in fact extremely difficult to uniquely characterise pressure sensor accuracy in presence of interfaces of different elasticity.

The proposal for a Technical Standard at the Italian Electro-Technical Committee is under study and will be formulated by the end of 2012. Hopefully, the proposal will be brought at a European level, too.

Hard work still remains to be done, however, to undermine some residual misuse and misinterpretation of plantar pressure measurement.

### REFERENCES

- Giacomozzi, Ann Ist Sup San 46:158-67, 2010.
- Giacomozzi, G&P, 32(1):141-4, 2010.

## The IMAR 3D-Force System: Have We Cracked It?

Graham P. Arnold (1), Rami. J. Abboud (1)

(1) Institute of Motion Analysis Research (IMAR), Department of Orthopaedic and Trauma Surgery, TORT Centre, University of Dundee, Scotland

### ABSTRACT

Plantar foot stress causing foot ulceration is a diabetic complication causing major economic burden throughout the world. It has long been thought that shear stresses on the plantar surface of the foot are a major contributing factor to the formation of these ulcers. Although there are many instruments available that measure the vertical foot pressure (vertical forces), there are currently no commercially available instruments to measure these important horizontal or shear forces. To overcome this limitation, the Institute of Motion Analysis and Research (IMAR) has designed a novel platform instrument to measuring the three dimensional forces (i.e. vertical pressure and shear forces) across the plantar surface of the foot. The aim of this paper is to present for the first time in detail the novel IMAR 3D-Force System, which is now protected by a patent (Figure 1).



Figure 1 IMAR 3D-Force System



## BIOMECHANICS IN SKIING – LOAD ANALYSIS, PERFORMANCE AND PERSPECTIVES

Stefan Josef Lindinger

Department of Sport Science and Kinesiology, University of Salzburg, Austria

### INTRODUCTION

Skiing, in its huge variety as a sport, different disciplines and particularly in its diverse impacts and dimensions for human life in certain countries, is an interesting field and creates lots of questions and tasks for science. Focusing the interaction skier – equipment/material – snow, lots of questions arise in terms of 1) loads on the human body and injuries, 2) material evaluation and optimization, 3) performance related issues and 4) learning processes in all skiing disciplines, interacting with factors like age, skill level, specific target groups, etc. Due to this complexity of these sports the aim was to perform numerous analyses in cross-country and alpine skiing, biathlon, snowboarding and ski jumping, as regards different questions already decades ago up to the present.

### METHODS

In numerous field/lab measurements complex kinematic, kinetic, EMG, inertial and ultra sound systems were used to examine above mentioned questions. 3D systems included 16-32 cams VICON-System or 3D Video-Technology (panned, tilted, zoomed; DRENK algorithms). 1-3 D force analyses was done by mobile systems like PEDAR (Novel, Germany) or self made, validated 2-3D force measurement bindings in cross-country/alpine skiing, biathlon and snowboarding. Inertial suits or single sensors (e.g. Humotion, Germany; 3D-accelerators-gyro- and magneto sensors + temperature and barometric pressure sensors) were used for pattern recognition. Balance and stability skills in different skiing sports, e.g. biathlon (stance & rifle pressure) were evaluated by mainly using pressure distribution systems (PEDAR Mobile, Novel, Munich, Germany; mean sway velocity, SDs of the centre of pressure (COP) and the rifle, load distribution – front/back leg, rifle forces in back shoulder).

### RESULTS

Selected results: *Cross-country skiing/biathlon:* Among several studies, the ideal push-off during skating was examining for top-elite skiers using race speed on snow, showing balanced force distributions between fore and rear foot in leg flexion phase and the first third of extension phase, corresponding to a stable back-forward balance during essential skate cycle phases (Lindinger, 2006).

Comparing Clap-Skate systems vs. Standard equipment used in World Cup, we found distinctly higher propulsive impulses of force for Clap systems and faster sprint times, due to higher torsion and bending stiffness and more efficient force transfer to the ski edge.

During classic skiing (diagonal, double poling with and without kick, etc.) and biathlon, performance, speed control, frequency choice and pressure distribution (Fig.2) related aspects were analyzed, presented in this lecture.

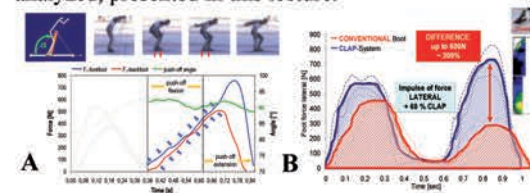


Figure 1: A) Ideal push-off model by Top-Elite skaters; B) Forces during CLAP-Skate vs. conventional boot/binding systems during high speed skating

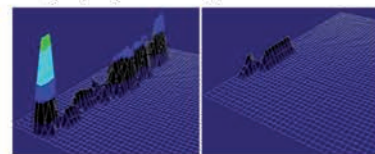


Figure 2: High and low shoulder pressure strategies during biathlon standing shooting in Elite biathletes.

*Alpine skiing:* Among lots of relevant topics (selected results) studies regarding 1) Biomechanics and injury prevention in elite alpine skiing, 2) The influence of course setting on patterns related to injury risk, and 3) Shank forces in alpine skiing, were analyzed. Add 1, different ski radii like Giant Slalom(GS)27m vs. GS 35-40m 2-3.8% lower forces were found in the less tailed skies, suggesting to use these prototypes. The force distribution within the turn showed a substantial force decrease towards end of the turn with GS40 which is of importance as regards specific ski racing injury mechanisms (Bere et al. 2011) and safety. Add 2) Interestingly besides clearly different paths of CoG using two extreme common course settings in GS, only small total ground reaction force (Fz) and CoG speed differences occurred, due to skidding in the tight turn variant. Add 3) Shank pressure/force measurements during alpine skiing were shown to be highly necessary to fully understand the force distribution mechanisms during high and low level alpine skiing tasks.

### CONCLUSIONS

Skier-material-snow interactions could be explained and applied in different relevant fields in skiing, leading to further questions to be investigated.

### REFERENCES

- Lindinger, S., Spektrum Bewegungswissenschaft, Bd. 4 - Meyer & Meyer Verlag, ISBN-13: 978-3-89899-105-6, Aachen 2005
- Bere, T. et al., Am J Sports Med, 39(7): 1421-1429, 2011



## RELATIONSHIP BETWEEN IMPACT RELATED VARIABLES AND PERCEIVED COMFORT IN DIFFERENT RUNNING SHOE CONSTRUCTION TECHNOLOGIES

Roberto C. Dinato<sup>1</sup>, Ivye L. R. Pereira<sup>1</sup>, Kenji Butugan<sup>1</sup>, Ana Paula Ribeiro<sup>1</sup>,  
Andrea N. Onodera<sup>1,2</sup>, Isabel C. N. Sacco<sup>1</sup>

<sup>1</sup> Physical Therapy, Speech and Occupational Therapy dept, School of Medicine, University of São Paulo, Brazil. <sup>2</sup> Biomechanics laboratory, DASS Sport & Style Inc., Ivoti, Brazil

### INTRODUCTION

Mechanical and biomechanical assessments are common to evaluate the effect of running shoe construction on impact attenuation. Different variables have been commonly used: plantar pressure, ground reaction force and mechanical test related variables, such as density, hardness and abrasion of sole and midsole materials. For recreational runners, comfort is the usual parameter used to choose a sport shoes and in biomechanical investigations of shoe performance, this variable has also been a study target for many years<sup>1,2</sup>. Visual analogue scales have been used to determine the perceived comfort<sup>3,5</sup>. Strong correlation between shoe comfort and biomechanical variables were found in the rearfoot, but not in the mid and forefoot<sup>4</sup>. However, other studies did not found any correlation between pressure variables and perceived shoe comfort<sup>6,7</sup>. Therefore, the aim of the present paper was investigate the relationship between comfort and plantar pressure, ground reaction force related variables and midsole density in four different construction technologies of running shoes: *Air*, *Gel*, *Adiprene* and *EVA*.

### METHODS

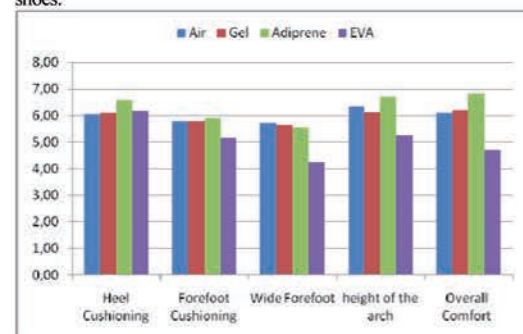
We recruited and analyzed 22 male recreational runners with a rearfoot strike pattern, with minimum experience of one-year training, and with a running volume of at least 20km/wk (39.3±6.6 yr, 76.1±9.2 kg). The plantar pressure were collected using the in-shoe Pedar-X system (at 100Hz) and ground reaction force was measured using a force platform AMTI (at 1000 Hz) during overground running in 4 different commercially available sport shoe construction (*Air*, *Gel*, *Adiprene* and *EVA*). Perceived comfort was evaluated using a validated visual analog scale based in Munderman et al. The test speed was controlled by two photocells (3.3±5%ms). Pressure related variables analyzed over rear, mid and forefoot were: contact area (CA), peak pressure (PP) and pressure-time integral (PI). Force related variables analyzed were: maximum vertical force (1<sup>st</sup> and 2<sup>nd</sup> peaks), loading rate (0 to 100% 1<sup>st</sup> peak) and impact transient (20 to 80% 1<sup>st</sup> peak). The density of midsole was assessed dividing the weight for the volume of a sample of the midsole material. Pearson correlations were calculated to determine the association of dynamic plantar pressure and force variables and density midsole with comfort. ANOVA for repeated measure was used to compare perceived comfort among shoes.

### RESULTS

The only shoes that were statistically different in the the perceived comfort were *Adiprene* and *EVA* shoes. There were significant strong and inverse correlation ( $r = -0.93$ ) between midsole density and overall comfort of shoes. There were no correlation between plantar pressure related

variables and comfort. Although not statistically significant, there was a moderate direct correlation between comfort and impact transient for the *Air* shoe ( $r = -0.32$ ) and push off rate and comfort for the shoe *Adiprene* ( $r = 0.42$ ).

Table 1 - Visual analogue comfort scale (cm) of four analyzed shoes.



### DISCUSSION

Our results agreed with part of the previous studies<sup>6,7</sup> who did not observe any relationship between plantar pressure variables and comfort. The strong inverse correlation between comfort and midsole density and the moderate inverse correlation between comfort and impact transient in *Air* shoes suggested that lighter shoes could be more comfortable and the impact transient may be an important variable that can predict the most comfortable shoes that would lead to lower impacts, and therefore have greater cushioning properties. *Adiprene* shoe showed to be the most comfortable shoe and its correlation results between comfort and push off rate, suggests that the most comfortable shoe can also generate more propulsion during running.

### CONCLUSION

The shoe lightness is one of the variables which translate into subjective comfort for the runner. However, the fragile relationship among comfort perception and biomechanical variables for shoes with different cushioning technologies, indicate that the comfort is not a good predictor for the reduction of plantar pressure and still not clear how this can help to reduce impact.

### REFERENCES

- 1 – Dixon, *Ergonomics*, vol. 51 n° 10, 1503-1514, 2008
- 2 – Hennig, *J. Applied Biomechanics*, 11, 299-310, 1995
- 3 – Mundermann et al., *Gait & Posture*, 38-45, 2002
- 4 – Milani, *Clinical Biomec.* Vol12, n°5, 294-300, 1997
- 5 – Miller, *Foot & Ankle Int.*, vol 21, 2000
- 6 – Jordan, *Gait&Posture*, vol 3:215-220, 1995
- 7 – Wegener, *The Am. J. S. Med.* Vol36,n°11, 2008



## FOOTFALL PATTERNS IN NATURAL MOTION RUNNING SHOES COMPARED TO CONVENTIONAL RUNNING SHOES

Nicolai. L. Mifsud, Nils. H. Kristensen , Uwe. G. Kersting

Center of Sensory-Motor Interaction, HST, Aalborg University, Aalborg, Denmark

### INTRODUCTION

In search for running footwear with the potential of reducing injury risk, the concept of Natural Motion (NM) running shoes has entered the market within recent years, a concept where the shoe enables a footfall pattern resembling barefoot running.

To the authors' knowledge no previous research has investigated how loading inside the shoe is changed immediately and following an adaptation period from conventional (C) to a NM running shoe.

The purpose of this study was to examine the biomechanical influence of training in a NM running shoe over a period of 6 weeks. The research question was: *How is the footfall pattern affected during initial contact when using NM compared to C running shoes?*

### METHODS

Sixteen male runners running >30km/week, with Foot Posture Index >1, and between 20 and 42 years of age were included. The test was designed as an intervention study with subjects being their own controls, using NM and C pre and post a 6-week training period. Shoes were assigned in random order for any given subject in each test with sufficient time to adapt prior to data recording. Five successful contacts were collected according to two criteria: 1) The pace should be within  $\pm 10\%$  of the 10 km race speed and was controlled by a pair of timing gates 2) No deviation from regular running subjectively inspected by the principle investigator.

In-shoe pressure was measured by Novel Pedar Insoles at 99 Hz. Ground reaction forces were collected by an AMTI-OR6-5-2000 platform at 1000 Hz, and motion capture data by eight Qualisys Opus 3 cameras at 250 Hz. Initial contact was defined as the first 50 ms of ground contact.

Statistical analysis was performed with an ANOVA-2 repeated measures, within subject. The individual post hoc tests between the factors shoe and test-time, were performed with Bonferroni adjustment, significance level set at  $p < 0.05$ .

### RESULTS

There were no significant differences in loading rate or ankle angle at touch-down between the different shoe conditions or test-times (Table 1). A tendency toward greater plantar flexion and loading rate was observed post test within shoe.

	C.Pre	C.Post	NM.Pre	NM.Post
LR[N/s]	47636	51284	51805	51943
SD	13056	11358	15715	11936
Ankle[deg]	112.7	124.8	112.9	121.8
SD	26.5	6.5	19.6	7.6

Table 1: LR, Maximum loading rate within the first 50ms. Ankle is the plantar flexion at touch-down.

Plantar pressure distribution showed a significant shift towards a lower heel pressure and greater anterior lateral pressure between pre and posttest within shoes. Greater anterior lateral pressure was observed using NM compared to C running shoes at post test.

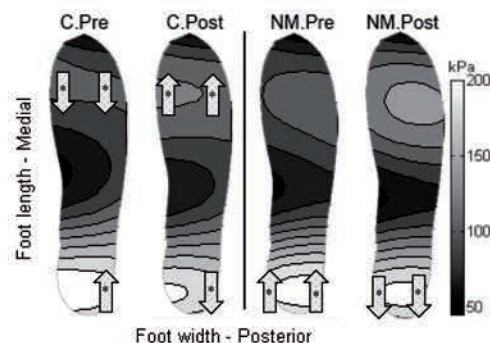


Figure 1: Overall mean plantar pressure distribution at pre and post test. \*, Difference within shoe pre to post. Statistically significant difference with Bonferroni adjustment, significance level  $p < 0.05$ .

### CONCLUSION

Following the adaptation period, a decreased heel pressure at initial contact was observed in both shoes and an increased anterior pressure in shoe C. This could be explained by a higher plantar flexor activation, resulting in quicker transfer of load to the forefoot and a higher loading rate. Our results indicate a change to increased forefoot loading resembling barefoot running which is carried over to running in a standard running shoe.

### ACKNOWLEDGEMENTS

We would like to express our thanks for providing testing footwear to Ecco™, Denmark, and Brooks™, Germany.

## PLANTAR PRESSURE DEPENDS ON THE PLAYING SURFACE IN TENNIS

Loïc Damm (1), Chelsea Starbuck (1), Nathalie Stocker (1), James Clarke (2), Matt Carré (2), and Sharon Dixon (1)

1. Exeter Biomechanics Team, Sport and Health Sciences, University of Exeter, United Kingdom, [www.sshs.exeter.ac.uk](http://www.sshs.exeter.ac.uk)
2. Sports Engineering Research Group, Dept of Mechanical Engineering, University of Sheffield, United Kingdom, [www.serg.group.shef.ac.uk](http://www.serg.group.shef.ac.uk)

### INTRODUCTION

One feature of tennis is the possibility of playing on different types of surfaces. Ball speed and bounce modification, as well as shoe-surface friction properties differ across tennis surfaces: these characteristics require specific strategies from the player. The aim of the present study was to characterise in-shoe pressure during tennis specific movements performed on hard court and artificial clay in two surface-specific shoes. It was hypothesised that players would avoid high pressure on clay to allow sliding since a more uniform distribution of pressure could facilitate sliding.

### METHODS

Two tennis surfaces were compared: artificial clay (AMB Pro Limited®) and cushioned acrylic hardcourt (DOE Sports, Greenset Comfort). Participants wore 2 different pairs of shoes on each surface (Adidas® Barricade 6.0 and Barricade 6.0 clay).

Seven (five males, two females) competitive tennis players (age  $21 \pm 1$  years; body mass  $71.14 \pm 12.05$  kg) performed 3 movements:

1. side jump at a distance equal to the height of their iliac crest, and jump back
2. open stance forehand: these two movements were each incorporated into a drill where the player was required to travel from the opposite side of the court
3. forehand plant

In-shoe plantar pressure distribution was recorded using the Pedar (Novel, Munich) insole system. For each movement the following variables were assessed during the final step of the dominant foot: peak and average pressure in the whole foot and in 8 regions of the foot (big toe, toes, medial and lateral forefoot, medial and lateral midfoot, medial and lateral heel) and number of unloading phases (defined as the occurrence of mean pressure value dropping below 40% of the maximal mean pressure). Conditions were compared using 2-way and 3-way repeated measures ANOVA ( $\alpha=0.05$ ).

### RESULTS

Significantly lower mean and peak pressure were measured during the side jump and plant running forehand on clay compared to hardcourt. An interaction between surfaces and foot regions appeared: post-hoc comparisons showed significantly lower pressure in the medial and lateral midfoot area on clay. During the forehand plant, unloading occurred more often on clay. No effect of shoes was noted.

	Surface	Hardcourt	Clay
Jump	Mean P	$46.5 \pm 7.9$	$40.8 \pm 6.1^{**}$
	Peak P	$428 \pm 76.5$	$388 \pm 76.3^{**}$
Open stance	Mean P	$38.8 \pm 6.4$	$35.3 \pm 6.6$
	Peak P	$416.9 \pm 82.7$	$395.3 \pm 59.8$
Plant	Mean P	$38.7 \pm 10.6$	$34.1 \pm 7.2^{**}$
	Peak P	$507 \pm 88.7$	$425.8 \pm 99.5^{**}$
	No. of unloading phases	$0.56 \pm 0.15$	$1.04 \pm 0.21^{**}$

Table 1: Mean, peak pressure (kPa) and number of unloading phases measured on hardcourt and clay surfaces. <sup>\*\*</sup> denotes an effect of the factor surface.

### DISCUSSION

The influence of surface is in agreement with previous studies (Girard et al., 2007, Strauss, 2011). A change in surface has a greater effect on plantar pressures than a change in shoe. On clay, limiting areas of high pressure could facilitate sliding by reducing the likelihood of any sticking. Unloading episodes could also be part of the strategy aiming at limiting high pressure on clay. The higher pressures on hardcourt support an association for increased levels of overuse injuries (Nigg and Segesser, 1988).

### REFERENCES

- Girard, O. et al, Br J Sports Med, 41(11), 733-738, 2007.  
 Strauss, D., Proceedings from SportSURF, 2011.  
 Nigg, BM and Segesser, B., Sports Med, 5:375-385, 1987.



# TRANSIENT IMPACT ESTIMATION USING PLANTAR PRESSURE TIME SERIES IN RUNNERS WITH PLANTAR FASCIITIS

Ana Paula Ribeiro, Roberto C. Dinato, Sílvia M.A. João, Isabel C.N. Sacco

Physical Therapy, Speech and Occupational Therapy Dept, School of Medicine, University of São Paulo, Brazil.

## INTRODUCTION

Foot overloads have been assigned as a pivotal factor in the development of the plantar fasciitis<sup>1,2</sup>. Few studies have investigated this factor during running and in different disease stages, such as chronic and acute pain phase<sup>3,4</sup>. These few results remain still inconclusive: (i) increase in vertical peak force in female asymptomatic runners<sup>3</sup> and (ii) no difference in plantar pressure distribution in runners with and without pain due to plantar fasciitis<sup>4</sup>. Nevertheless, some authors<sup>3,5,6</sup> have been emphasizing the importance of the impact transient as a mechanical factor that contributes to the incidence of stress fractures and plantar fasciitis in runners. It has already been observed a higher loading impact<sup>6,7,8</sup> in runners who developed stress fractures. Based on these last results, it is important to estimate and comprehend the impact transient pattern in natural environment of running in runners with plantar fasciitis in different disease phases. The aim of this study was to analyze the plantar pressure time series and estimate the impact transient in recreational runners with plantar fasciitis in the chronic and acute phases of the disease.

## MATERIALS AND METHODS

Eighty-five recreational runners were evaluated: 40 healthy controls 40 healthy controls (CG) (35±9yr, 66.8±12.0kg, 1.7±0.9m) and 45 with diagnosed plantar fasciitis (by US): 30 in the acute phase with foot pain (APF) (45.4±8.1 yr, 69.6±14.0 kg, 1.68±9.2 m) and 15 in the chronic phase without foot pain (CPF) (38±3yr, 72.3±10.0 kg, 1.8±0.8 m). The pain was evaluated using a Visual Analogue Scale. The plantar pressure was evaluated by Pedar X system during running in a 40 meters track at 12±5% km/h. Runners used a standardized sport footwear. All runners exhibited a heel strike pattern of running. The impact transient and the loading rate were estimated by plantar pressure time series. Force, force-time integral and contact area were evaluated over the rearfoot, midfoot and forefoot. The data were processed in a custom written Matlab function. Groups were compared by repeated measures ANOVA, followed by Tukey post hoc test (p<0.05).

## RESULTS AND DISCUSSION

The APF group showed a mean pain of 7±2 consecutive months and an intensity of 5±2 cm.

Table 1- Mean, standard deviation and comparison among groups: fasciitis and the control of transient impact during running.

	APF(1)	CPF(2)	CG(3)
Transient impact (20 -80%) (BW/s)	70.1±29.1	83.5± 60.7	56.6± 21.5
<i>p</i>	0.040 (1-2)*	0.020 (2-3)*	0.020 (1-3)*
Average load rate (0-100%) (BW/s)	39.7± 8.7	37.6 ±12.4	30.6 ±9.8
<i>p</i>	0.873 (1-2)	0.025 (2-3)*	0.018 (1-3)*

Table 2- Mean, standard deviation and comparison among groups with plantar fasciitis (SPF; APF) and the control (CG) of plantar pressure variables during running.

Variable	Group	Rearfoot	Midfoot	Forefoot
force (N)	APF (1)	0.300±0.05	0.147±0.02	0.620±0.11
	CPF (2)	0.231±0.03	0.156±0.02	0.639±0.10
	CG (3)	0.209±0.04	0.154±0.03	0.620±0.05
	<i>p</i>	0,001*	> 0,05	> 0,05
Force integral (N.s)	APF (1)	0.265± 0.12	0.143± 0.04	0.630± 0.11
	CPF (2)	0.258± 0.12	0.148± 0.03	0.627± 0.07
	CG (3)	0.228± 0.04	0.151± 0.03	0.619± 0.05
	<i>p</i>	0,050*	> 0,05	> 0,05
Contact area (cm <sup>2</sup> )	APF (1)	0.197±0.02	0.238± 0.01	0.594± 0.05
	CPF (2)	0.186±0.04	0.229± 0.02	0.572±0.03
	CG (3)	0.198±0.02	0.252± 0.10	0.560± 0.02
	<i>p</i>	> 0,05	0,001*	0,001*

\*significant difference between groups

The impact transient was higher in runners with plantar fasciitis (APF and CPF) compared to controls. Although this variable is an estimation based on the plantar pressure time series, our findings suggest that the impact transient could be considered an important factor related to the onset of plantar fasciitis or still to the pain worsening in the acute phase of the disease, as observed in runners who developed stress fracture<sup>7,8</sup>. Runners in the acute phase of the disease presented smaller vertical forces over the rearfoot. This result suggests that runners with pain perform a compensatory mechanism which may lead to an overloading on the contralateral foot contributing to bilateral fasciitis. Furthermore, based on the force results on the rearfoot of CPF, we can suggest that insole treatment to redistribute plantar loads can be of better use in chronic phases of the disease. Pohl *et al.* (2009)<sup>1</sup> also observed higher vertical forces on the rearfoot in female runners. This pattern could be compensation to the smaller contact area over the midfoot and forefoot observed in plantar fasciitis group compared to control.

## CONCLUSION

The estimated impact transient could be an important factor to be evaluated in runners in different plantar fasciitis stages (acute and chronic) since this factor can contribute to its development or worsening.

## REFERENCES

1. Bedi and Love, Foot Ankle Int. 19(3): 153-156, 1998.
2. Wearing *et al.*, Phys Ther. 87(8): 1002-8, 2007.
3. Pohl *et al.*, Clin J Sport Med. 19(5): 372-376, 2009.
4. Ribeiro *et al.* 2011, Clinical Biomech. 26(2): 194-199, 2011.
5. Van Gent *et al.* Br J Sport Med. 41: 469-480, 2007.
6. Milner *et al.* Med. Sci. Sports Exerc. 38(2): 323-328, 2006.
7. Davis, Milner and Hamil *et al.* Med Sci Sports Exerc. 36:S58, 2004.
8. Crowl e Davis. J Orthop Sports Phys Ther. 40(4): 206-213, 2010.

## SYNCHRONIZATION OF MEASUREMENT SYSTEMS FOR DETERMINING THE PHYSICAL WORK LOAD

P Löwis<sup>1)</sup>, H Kaiser<sup>1)</sup>, T Consmüller<sup>2)</sup>, R Blüthner<sup>1)</sup>, C Hanisch<sup>1)</sup>, M Schust<sup>1)</sup>, A Kalpen<sup>3)</sup>

1. Federal Institute for Occupational Safety and Health, Berlin, Germany
2. Epionics Medical GmbH, Potsdam, Germany
3. novel gmbh, Munich, Germany

### INTENTION

The investigation of stress-strain-relationships between physical load and possible detrimental effects on health requires objective measurements of biomechanical parameters. At work places, physical demands are dominated by lifting, carrying, pushing and pulling objects of different weight. Bended and distorted body postures seem to have the most adverse effects. Therefore, the measurement of body postures and movements, forces and pressure distributions are of special interest. For this purpose, three systems were selected:

1. Epionics SPINE. Two Strain-gage stripes are fixed in two plaster tubes parallel to the right and left sides of the spine. The system measures the bending of the stripes and the three-dimensional acceleration at both ends of each panel (Epionics, 2012).
2. novel pedar. Equipped with a pair of measurement insoles, the system measures the pressure and its distribution. Additionally, the force on both feet can be obtained (novel, 2012).
3. Xsens MVN Biomech is a motion analyzing system. Seventeen sensors are distributed over the whole body. The sensors measure accelerations, earth-magnetic field and rate of turn values in three dimensions depending on the mode (Xsens, 2012).

### CHALLENGE

The entire equipment should be wearable without massive interference of the working task. For offline analysis the three systems should measure synchronously with a defined start point. The end points need not necessarily be the same but it would be an advantage. For these demands, the systems have different properties:

The Xsens system in its base state is not able to deliver or receive any sampling rates (clocks) or start signals (triggers). The recording has to be started by pushing a button. The integrated time code and remote control function was not usable for the type of required synchronization.

The Epionics system in its basic state is not capable of communication with external systems.

The novel system is able to send or receive signals to/from external devices by fibre optic cable (foc) (or if necessary by TTL) and to accept external signals as external sampling rate or simply as a start signal with further use of its own internal sampling rate.

### REALIZATION

A modification of the Epionics System by the manufacturer enabled the acceptance of an external start signal (trigger) and the output of the internal sampling rate (clock, 50 Hz) to other external devices by foc. The pedar system was switched to a mode where it works as slave. A first frame trigger and a clock signal (50Hz) is received from the Epionics system.

A modification of the Xsens System was assumed to be impossible. The system had to work as master and to get a marker or something similar to define a start point. Therefore a 'Synchrobox' was constructed. It contains a button for setting a start signal by hand and a logical circuit. Pushing the button produces a rectangular pulse in the magnetic recording of the XSens system, which has been started before, and simultaneously a start signal for Epionics as soon as the next frame is taken by the internal sampling rate of XSens (100Hz). So, the synchronization was realized for two of the three systems with a marked frame in the third one.

### RESULTS

Several tests have been done in two kinds of companies. They were performed in firms with working activities in food storage and in production. The experiences with the realized synchronization will be presented with respect to feasibility and management of the entire equipment.

### REFERENCES

[www.epionics.com](http://www.epionics.com)  
[www.novel.de](http://www.novel.de)  
[www.xsens.com](http://www.xsens.com)



## PRESSURE MEASUREMENT IN PRESSURED TISSUES: NEW PERSPECTIVES IN CANCER RESEARCH

Julie R. Steele (1)

1. Biomechanics Research Laboratory, University of Wollongong, NSW, Australia

### INTRODUCTION

Cancer is one of the leading causes of death internationally, accounting for approximately 13% of all deaths (~7.6 million people) in 2008 (WHO, 2010). Deaths from cancer are projected to continue to rise internationally and will exceed 13.1 million in 2030, with the incidence of cancer rising dramatically as the world's population ages.

Despite an increase in cases, outcomes for patients diagnosed with many cancer types have substantially improved, leading to a concurrent reduction in mortality rates. Consequently, more individuals than ever before are living with the effects of cancer and its treatment. With the increasing number of cancer survivors, it is imperative that greater efforts are directed towards improving the physical functioning and quality of life of individuals living with a diagnosis of cancer.

### BREAST CANCER & EXERCISE

One of the most effective ways that can enhance quality of life in cancer survivors is participation in regular physical exercise. However, in a recent online survey completed by 482 breast cancer survivors (mean age 53.25 years; range 23-77 years), the top three barriers to exercise were procrastination, fatigue, and not being able to find a comfortable bra to exercise in (Gho *et al*, 2010a). As bra discomfort can be externally modified, via changes to bra design, it is an ideal for target for intervention. Our aim is therefore to systematically investigate factors that affect the fit and design of bras worn by breast cancer survivors in order to develop innovative breast support strategies so these women can participate in physical activity in comfort.

### PRESSURE MEASUREMENT & CANCER

Breast cancer survivors have reported numerous bra discomfort issues when they attempt to participate in physical activity, including the bra fabric aggravating sensitive and injured skin following radiation therapy, the bra band pressing on drain sites, and the bra band being unable to cope with fluctuations in tissue oedema (Gho *et al*, 2010b). As many of these issues are caused by excessive pressure between the bra and breast cancer survivor's breast tissue or tissue covering their torso, it is imperative that we understand the effects of changes to bra design components on these pressures.

To develop a comprehensive understanding of the bra-tissue interface, we quantify the pressures generated under the bra straps, cup and band using a Pliance-c Expert (Novel Inc.) system, and custom-designed calibrated pressure sensors. Pliance-c software is then used to mask the relevant sensors in order to calculate the mean and peak pressure (N/cm<sup>2</sup>) for each condition. Pressure data are collected during both static stance and, in conjunction with other biomechanical data, while participants exercise on a treadmill wearing randomised experimental bra conditions. Participants are also asked to rate their breast and bra discomfort after each trial using a visual analogue scale in order to be able to relate the pressure data with discomfort scores.



*Figure 1: Measuring pressure exerted by the bra band, strap and cup of a breast cancer survivor.*

### CONCLUSIONS

Measuring pressure when developing intervention strategies for cancer patients can provide vital information pertaining to how external devices, such as bras or compression sleeves for lymphoedema, impact upon sensitive tissues that may have been compromised during cancer treatment.

### REFERENCES

- WHO, Cancer Fact Sheet No. 297, 2012.
- Gho SA *et al*, Report to BCNA, 2010a.
- Gho SA *et al*, Support Care Cancer, 18:735-741, 2010b.

## RELATIONSHIPS OF SELECTED PARAMETERS OF GAIT TOWARDS THE LATERALITY OF LOWER EXTREMITIES.

Martin. Zvonar, Katerina. Kolarova, Jindrich. Pavlík, Sylva. Hrebickova

Department of Kinesiology, Faculty of Sports Studies, Masaryk University, Czech Republic

### BACKGROUND

A number of researches have shown that in current population, walking is still a growing source of natural physical activity, mainly for adults (Nykodým 2007, Sigmund 2005). Technique of walking is an individual physical manifestation formed during the period of adolescence and also later under the influence of work load, health, physical activity or the condition of motor system.

Every human has some predispositions to prefer one of the sides of their body; laterality affects a number of motor activities, whether connected to work or leisure. In a cross-sectional research we focused on the relationship of laterality towards selected force and time parameters of walking in woman aged over 30. These parameters are as follows:  $F_1$  – peak force (applied to body weight) during loading response (LR),  $F_2$  – peak force (applied to body weight) during terminal stance (TSt),  $F_a$  – average vertical force (applied to body weight) of whole stance,  $t_a/t_p$  – rate of time of active (TSt) and passive (LR) part of plantar contact with surface (stance).

With regard to usual manifestation of laterality – preferring the dominant lower limb for take-off and the other one for swing – we suppose that the given characteristics could differ with these limbs. The aim of the study is to research differences between right and left lower limbs regardless of dominance and subsequently with regard to the dominant extremity.

### METHODS

Sixty women with ordinary physical activities participated in the study. They were divided into three groups according to their age (A 30 – 39, B 40 – 49, C over 50). Each group contained 20 women. The average age in the first group was 33.9 ( $\pm 2.6$ ), in the second 42.6 ( $\pm 3.0$ ) and in the third one 57.0 ( $\pm 6.4$ ).

Laboratory survey with capacitive pressure insoles (Pedar Mobile, Novel Munich, 99 sensors, 50 Hz) was carried out in the following way: each woman performed three attempts of natural walking in the length of 15 m, two of them were for training; the final attempt was monitored. Three gait cycles were assessed: 3 steps of the left and 3 steps of the right foot.

Laterality was tested according to Ruisel (1976).

Out of the statistical methods of data processing, we chose ANOVA method and its non-parametric version – Kruskal-Wallis test.

### RESULTS

Analysis of variance has not proved statistically significant differences in the values of the parameters judged neither according to factors nor their combinations ( $p > 0.1$ ). A small effect size ( $\eta^2 = 0.058$ ) could be observed between groups of dominant right or left limb respectively, and medium effect size ( $\eta^2 = 0.068$ ) in groups of different age.

Kruskal-Wallis test confirmed this effect size. The difference between the values of  $t_a/t_p$  in groups with dominant right or left lower limb respectively (1.149; resp. 1.233) was considered significant. Other significant differences were recorded in the test between age groups A and C in the values of relative maximal force in stance passive part ( $F_1 = 1.116$  N/kg resp. 0.998 N/kg), further, in the values of relative maximal force in stance active part ( $F_2 = 1.190$  N/kg resp. 1.104 N/kg) and in the values of  $t_a/t_p$  rate (1.145; resp. 1.084). No other relationships (e.g. between dominant and non-dominant limbs) have been statistically proved.

### DISCUSSION

From the point of view of laterality, a different  $t_a/t_p$  rate in groups with dominant right or left limb respectively has been found. Force variables did not manifest any differences. Likewise, no differences have been found between the right and left limbs regardless of dominance.

Observing gradual decrease in relative ground reaction forces with growing age was more successful – however, significant changes were proved only between the youngest and the eldest groups. Between these groups, a decrease in  $t_a/t_p$  was also obvious, i.e. in the share stance active part has in its total duration.

### REFERENCES

- Nykodým et.al., Tělesná kultura 30:2,59-71, 2007.
- Ruisel Teor.Praxe těl.vých. 8: 461-466, 1976.
- Sigmund et.al., Tel.vych.Sport. 15,3-4, 23-27, 2005.



## PLANTAR PRESSURE DISTRIBUTION IN INDIAN PEOPLE WALKING WITH VARIED EXTENT OF FOOTWEAR USE

Rajani. P. Mullerpatan

MGM School of Physiotherapy, MGM Institute of Health Sciences, Navi Mumbai, India

**Background:** Barefoot walking is a continued practice in Indian in varying proportions in urban and rural lifestyle. Tropical climate, cultural influence and socio-economic factors determine extent of footwear use. It is speculated that extent of footwear use may affect plantar sensation. Present study compared plantar pressure distribution among people at different plantar sensory level which is a part on an ongoing study aimed to assess plantar cutaneous tissues among healthy people with varied footwear use compared to people with diabetes.

**Methods:** 41 healthy subjects without neuromusculoskeletal disorders causing gait impairment were included. Plantar sensation was scored using 4.56 S-W monofilament (3.1g) from 0-4 on four plantar sites namely: great toe, first metatarsal head, fifth metatarsal head and heel (Collins S et al., 2010). All subjects were divided in 5 groups based on their plantar sensory score i.e. 0,1,2,3,4,5 (n=20,2,1,3,15 respectively). Peak plantar pressure (PPP) was measured using pedar in-shoe pressure measurement system, novel, Germany. All subjects walked for 10m on an even terrain using standard footwear at their natural speed. Considering the variation in body weight among 5 groups plantar pressure (kPa) per kg of body weight was computed with a ratio of peak plantar pressure (kPa) over right foot and body weight (kg) because body weight (B.W.) is known to influence plantar pressures (Hills AP et al, 2001). Plantar pressure per kg body weight was compared across 5 groups using ANOVA with gait velocity as a co-variant.

**Findings:** 60% of the people who began using footwear later in life and used it occasionally scored 0 with 4.56 monofilament. Whereas all people who used footwear since their walking age scored 4. Plantar pressure per kg body weight was significantly different between the 5 groups ( $p>0.01$ ). However linear polynomial contrast did not reveal significant trend in plantar pressures among 5 groups.

**Interpretation:** It is likely that majority of people who walk barefoot predominantly did not perceive touch pressure sensation because it is known that such people produce thickened callus on the sole of foot so that certain parts of sole are unable to detect 5.07 filament (Mitchell PD et al, 2001). Significant difference in plantar pressure per kg body weight among 5 groups indicates that healthy people with different plantar sensory perception sustain different plantar pressures. Considering the influence of plantar sensation on peak plantar pressures (Caselli A et al, 2002) it would be reasonable to expect a linear rise in peak pressure across the 5 groups scoring from 0-4. But the non-significant difference could be due to small sample size. Longitudinal study with a larger sample size compared to people with diabetes is in process to provide more information on this topic.

**TABLE**

Groups based on sensory score (n)	0 (20)	1 (2)	2 (1)	3 (3)	4 (15)
BMI kg/m <sup>2</sup>	19.53	18.3	19.03	18.43	22.89
Pressure (kPa)/kg body weight	5.53	6.02	5.87	6.15	5.57

*Table 1: Subject characteristics and plantar pressure values.*

### EQUATIONS

Plantar pressure per kg body weight=PPPxB.W.

### REFERENCES

- Caselli A *et al*, Diabetes Care 25:1066-1071,2002.
- Collins S *et al*, Disabil Rehabil 32: 2019-2027, 2010.
- Hills AP *et al*, Int J Obesity 25: 1674-1679, 2001.
- Mitchell PD *et al*, Lepr Rev 72: 143-150, 2001.

## LONGITUDINAL STUDY OF CHANGES IN FOOTSTEP FORCE DISTRIBUTION DURING PREGNANCY.

Martina Cernekova, Petr Hlavacek, Eva Naplavova, Eva Kutalkova

Department of Physics and Materials Engineering, Faculty of Technology,  
Tomas Bata University in Zlín, Czech Republic

### INTRODUCTION

During pregnancy, the body of a woman undergoes many changes. To a certain degree, these changes affect practically every part of the woman's organism. Gradually, this even leads to the modification of the kinetic system. During pregnancy, female sex hormones cause the relaxation of muscles, ligaments and tendons. Another factor affecting the kinetic system during pregnancy is the growing weight of the woman. The increase in weight leads to an increased load on the lower limbs when standing and during movement. Under the impact of the different weight distribution in the body, the center of gravity also changes - it begins to shift forward. All the aforementioned factors affecting the posture of the woman have an impact on the biomechanics of walking and also manifest themselves on the foot<sup>1,2,3</sup>. The question is to what individual degree is the adaptation of the lower limbs and feet to the increased load and other stress and to what degree is it possible to find common features of this process in healthy pregnant women. Research conducted to date has not concurred in its conclusions, which may be caused by the diverse methodologies of experiments. If it is possible to find common features of changes in the foot dimensions and the distribution of footstep force, this information would be possible to use for the design or selection of appropriate footwear and for improving foot care for pregnant women.

### METHODS

Participating in the experiment were 12 pregnant women (25-33 years), who were contacted in cooperation with a midwife. A condition for selection was a positive health status, actual physiological pregnancy and non-multiple pregnancy. The first measurement was conducted at about the middle of the second trimester (15th - 23rd week of pregnancy) and additional measurements took place in intervals of 2-3 weeks until birth (each woman completed 5-6 measurements). During each measurement, the weight increases were monitored (in regard to the status at the beginning of the pregnancy) and the toe girth perimeter was measured when relieved and during stress. The dynamic measurement of footstep force distribution was performed on an EMED<sup>®</sup>-at device.

The subject walked with a relaxed, natural gait across the sensor surface in order to measure 4-5 steps. The gait speed or length of step had no effect. During each visit, 4 records were measured for the footstep of the right foot and 4 for the left foot. From these measurements, the average maximum force value, peak pressure, contact area and other variables were determined using novel scientific software. In addition to the total assessment, an evaluation was also conducted in masks - rearfoot 30%, midfoot 30%, and forefoot 40%<sup>1</sup>.

### CONCLUSIONS

The assessment of measured data showed that, consistent with expectations, manifest for most subjects were an increasing tendency in the overall maximum force, which probably relates to the increase in weight. The common feature of changes in the measured women was also a decline in the average velocity of COP over the course of pregnancy. However, in the selected group of women, an increasing peak pressure was not successfully demonstrated and there was no uniform tendency here in its redistribution. The results relating to the increase in contact area in rearfoot and midfoot could not be unequivocally confirmed<sup>1,2,3</sup>.

It seems that a woman's organism is capable of adapting to gradually increasing load over the course of pregnancy and the cushioning mechanisms of the body and lower limbs are capable of preventing large increases in local pressure on the surface of the foot. The method for adaptation, however, is probably very individual, from which it follows that it is very difficult to establish uniform requirements for footwear appropriate for pregnant women.

### REFERENCES

1. Ribeiro A. P. *et al*, Changes in the Plantar Pressure Distribution During Gait Throughout Gestation. JAPMA Vol.101(5), P.415-23. 2011.
2. Gaymer C. *et al*, Midfoot Plantar Pressure Significantly Increases During Late Gestation. The Foot Vol.19(2), P.114-6. 2009.
3. Nyska M. *et al*, Planter Foot Pressures in Pregnant Women. Israel J. of Med. Scien. Vol.33(2), P.139-146. 1997.

## HOW EARLY CAN THE CHILD'S FOOT TYPE BE DETECTED? RETROSPECTIVE ANALYSIS OF LONGITUDINALLY ASSESSED ARCH INDEX VALUES

Dieter Rosenbaum (1), Kerstin Bosch (2)

1. Movement Analysis Lab, Institute for Exp. Musculoskeletal Medicine, University Hospital Münster, Germany
2. Sozialpädiatrisches Zentrum Westmünsterland, St. Vincenz-Hospital Coesfeld, Germany

### INTRODUCTION

The child's foot has been shown to develop rapidly as soon as weight-bearing begins (Bertsch 2004, Unger 2004, Bosch 2007) and will present distinct individual characteristics already at an age of about 5 to 6 years (Rosenbaum, 2011). However, it is not clear how early the development of a persisting high-arch or flat foot emerges, i.e. at what stage the first changes between foot types might be detected.

Therefore, the aim of this study was to retrospectively analyze the development of children's foot loading patterns with respect to certain foot types. Potential findings might help to predict the individual foot shape in upcoming years.

### SUBJECTS & METHODS

The data of the longitudinal 'Kidfoot Münster' study were re-evaluated for 65 children who had completed 8 years of observation. For each child, a total of 16 appointments were used for the assessment of plantar pressures (Emed X, free barefoot walking, 5 trials per foot). The arch index (AI) was determined with the Novel software and all 130 feet were sorted according to their last AI at the 8-year visit.

These feet were subdivided into 3 groups, with a low ( $<0.1$ ,  $n=36$ ), intermediate ( $0.1$  to  $0.2$ ,  $n=56$ ) or high AI ( $>0.2$ ,  $n=38$ ) corresponding to relatively high-arched, normal or flat feet. These subject groups were then compared with respect to their previous AIs at all 16 appointments.

### RESULTS

The three groups showed an average AI of  $0.05 \pm 0.03$  for high-arch,  $0.16 \pm 0.03$  for normal and  $0.24 \pm 0.02$  for flat feet. The differences between the groups are significant for all 16 visits ( $p < 0.0001$ ).

The rate of changes appears similar in the three groups (Fig. 1) so that the overall development is comparable for the foot types.

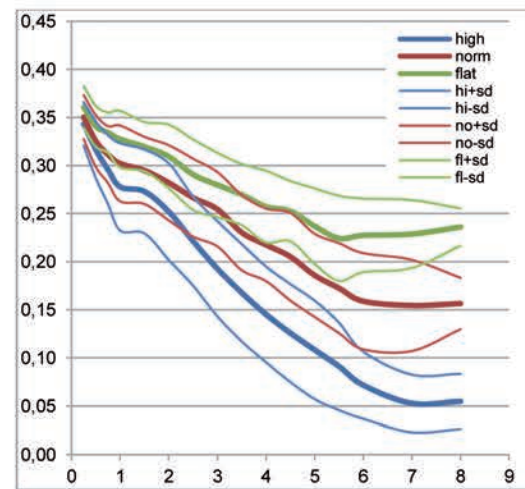


Fig. 1: Development of the arch index over 8 years of walking experience.

### DISCUSSION & CONCLUSION

Even though the groups overlap to a certain degree when the range (mean  $\pm$  SD; Fig. 1) of AI values is considered, the groups that were retrospectively identified at age 9 seem to separate early in their individual development.

Therefore, predictions about the later development of distinct foot shapes might be possible already at an early stage of the growing foot.

### REFERENCES

- Bertsch *et al.*, Gait & Posture 2004
- Bosch *et al.*, Gait & Posture 2007
- Unger *et al.*, Foot & Ankle Int 2004
- Rosenbaum *et al.*, DKOU 2011

### ACKNOWLEDGEMENT

Sincere thanks to the subjects & parents for their continued loyalty and the DFG for financial support.

Contact: [diro@uni-muenster.de](mailto:diro@uni-muenster.de)



## CROSS-SECTIONAL COMPARISON OF SELECTED GAIT CHARACTERISTICS OF WOMEN OF DIFFERENT AGE.

Pavel Korvas, Radek Musil, Jan Došla, Jan Cacek

Department of Kinesiology, Faculty of Sports Studies, Masaryk University, Czech Republic

### INTRODUCTION

Population in the Czech Republic is referred to as walking population. With ever decreasing volume of physical load of present population, walking becomes one of significant physical activities which play the part of natural physical load during a working day (Fromel 2005, Nykodým 2007). An individual learns and gains specific characteristics of gait during the period of growing (Zvonař 2010). Information about the differences in common middle-aged and elder-aged population can suggest tendencies of changes in gait structure as influenced by age.

This cross-sectional study compares gait force and time characteristics of women aged over 30.

### METHODS

Subjects: 60 women with ordinary physical activities participated in the study. They were divided into three groups according to their age (A 30 – 39, B 40 – 49, C over 50). Each group contained 20 women. The average age in the first group was 33.9 ( $\pm 2.6$ ), in the second one 42.6 ( $\pm 3.0$ ) and in the third one 57.0 ( $\pm 6.4$ ), average BMI in the first group was 23.0 ( $\pm 2.2$ ), in B 24.0 ( $\pm 3.3$ ) and in C 25.9 ( $\pm 5$ ). Instrumentation: questionnaire, capacitive pressure insoles in the shoe (Pedar Mobile, Novel Munich, 99 sensors, 100 Hz). Protocol: laboratory survey, each woman performed three attempts of natural walking in the length of 15 m, two of them were for training, the final attempt was monitored. Three stances of each leg were assessed, always from between the third and eighth steps. Parameters: Five parameters had been chosen for monitoring, three recording force characteristics of gait and two time parameters.  $F_1$  - force peak during loading response (LR),  $F_2$  - force peak during terminal stance (TSt),  $F_a$  - average vertical force of whole stance, mBW - plantar vertical force in multiple of body weight, time of stance ( $t$ ), time of active and passive part of plantar contact with surface (stance) [time of stance passive part ( $t_p$ ) is time from initial contact (IC) to the end of MSt, time of stance active part ( $t_a$ ) is time from the start of TSt to terminal contact (TC)]. Statistics: ANOVA

### RESULTS

A tendency of gradual decrease in the volume of vertical force affecting the foot in mBW has been observed in dependence on increasing age of the observed women in all selected force parameters ( $F_1$ ,  $F_2$  and  $F_a$ ). This manifests a natural development

of gradual decrease in human force abilities depending on their age. Significant differences were found between groups A and C for  $F_1$  in BW ( $p=0.008$ ) and for  $F_2$  in mBW ( $p=0.039$ ). For  $F_a$ , in the course of the stance, no significant differences have been found between the groups.

Gr.	$F_1$ (N, mBW)		$F_2$ (N, mBW)		$F_a$ (N, mBW)	
	L	R	L	R	L	R
A	687	705	761	740	744	750
	1,11	1,13	1,22	1,19	1,2	1,21
B	740	748	796	774	790	783
	1,08	1,08	1,15	1,12	1,15	1,14
C	694	691	730	772	771	786
	1,0	1,0	1,08	1,11	1,11	1,13

Tab.1 Vertical force values of all groups

The average time of one stance increases with an increasing age; a significant difference has been found between groups A and C by 9.4 % ( $p=0.006$ ) and between B and C as well by 7.8 % ( $p=0.02$ ). This increase is mainly a consequence of prolonging the time of stance active part (terminal contact and preswing) in elder aged groups. If compared to group A, the time of stance active part was prolonged in C by 18.2 % and in B by 14.7 %. Increasing ratio between passive and active parts of stance in elder age groups result from these findings: a significant difference by 15.2 % was found between groups A and C ( $p=0.037$ ). Differences between the right and left legs have not been found in any of the groups.

Gr.	$t$	$t_p$	$t_a$	$t_a / t_p$
A	0.64	0.30	0.33	1.12
B	0.65	0.31	0.34	1.17
C	0.70	0.31	0.39	1.29

Tab.2 Time characteristics of stance for all groups

### CONCLUSIONS

In the observed groups of women, a tendency has been found to decrease the volume of vertical force affecting the foot in the course of the stance in dependence on increasing age. In groups of older age, the performance of stance is longer, mainly through prolonging the time of stance active part in the stages of terminal stance and preswing.

### REFERENCES

- Fromel *et.al.* Olomouc, Palacky university, 2005  
 Nykodým *et.al.* Tel.kult.30:2,59-71, 2007.  
 Zvonař *et.al.* Brno, Masarykova univerzita, 2010.

## DOES GENU VALGUM AND/OR FLAT FOOT PLAY A ROLE IN DYNAMIC PLANTAR PRESSURES AND STATIC FOOTPRINTS IN OBESE AND NON OBESE CHILDREN?

Bernecker, R. (1) Weghuber, D. (2) Landauer, F. (3) Huber, G. (2) Landkammer, Y. (1) Wicker, A. (1)

1. University Clinic for Physical Medicine and Rehabilitation, PMU Salzburg, Austria
2. University Clinic for Pediatrics and Adolescent Medicine, PMU Salzburg, Austria
3. University Clinic for Orthopaedics PMU Salzburg, Austria

### OBJECTIVE

The aim of this study was to determine differences in dynamic plantar pressures during gait and static footprints during 10 seconds 'one-leg-stand' displayed by obese-with genu valgum and/or flat foot- and non obese children with normal mechanical axis and feet..

### MATERIAL AND METHODS

Thirty four children, divided into thirteen obese (age 12.9+/-2.5 y; BMI 31.2+/-4.6kg/m<sup>2</sup>) and nineteen non obese (age 11.6+/-2.7 y; BMI 18.0+/-2.5kg/m<sup>2</sup>), voluntarily participated in this study. Dynamic plantar pressures and static footprints were analyzed by using an emed pedography platform system (novel GmbH, Munich, Germany).

### MEASUREMENTS

Height and weight were measured to calculate BMI. Additionally BMI was entered in percentiles. Right and left dynamic plantar foot pressure variables were measured during gait using an emed-q100 platform (novel GmbH, Munich, Germany), just as static footprint variables during 10 seconds 'one-leg-stand'. Under dynamic conditions right and left contact area, maximum force (normalized to bodyweight), peak pressure and contact time (%ROP) data for different areas of each participant's feet were collected using an emed-q100 platform. Under static conditions the same data were collected except contact time, which was committed to 10 seconds.

### RESULTS

Only during 'one-leg-stand' the obese children had a significantly greater contact area ( $p < 0.001$ ). In case of walking the obese children showed a significantly higher ( $p < 0.001$ ) contact time (%ROP) in all foot areas except the toes. Neither maximum force nor peak pressure showed significant differences under the static setting. Under the dynamic setting obese children showed significantly lower ( $p < 0.001$ ) outcomes concerning maximum force (normalized to bodyweight) in medial and lateral hind foot, just as the big toe. Whereas peak pressure showed exactly the opposite. That is significantly higher peak pressure results ( $p < 0.001$ ) concerning the obese children.

### CONCLUSIONS

In general more significant differences were observed under the dynamic setting. This indicates that a dynamic setting could be of bigger importance than a static situation, especially in clinical questioning.

Existing studies (see below) describe that obese children show higher forces and peak pressures while walking and standing. In this concrete case some surprising findings were detected. Despite of genu valgum and/or flat foot plus obesity, the obese participants seem to be able to compensate total maximum forces. Whereas peak pressure showed the opposite. It seems that there are some compensatory mechanisms, which must be exactly reviewed.

Therefore further investigation is required to identify the functional procedure containing mechanical axis and feet especially in view of the fact that obese children must be lead to physical activity with exact recommendations.

### REFERENCES

- Dowling *et al*, Int J Obes Relat Metab Disord 28(11): 1514-9, 2004.  
 Dowling *et al*, Int J Obes Relat Metab Disord 25(6): 845-52, 2001.  
 Mickle *et al*, Int J Pediatr Obes 1(3): 183-8, 2006.  
 Taisa Filippin *et al*, Foot Ankle Int 29(11): 1141-4, 2008.

## THE EFFECTS OF FOOT TYPE AND HERITABILITY ON BALANCE AND PLANTAR PRESSURE DISTRIBUTION IN FEMALE TWINS AGED 18-35 YEARS OLD

Bitā. Shakibi (1), Heydar. Sadeghi (1), Raghad. Mimar (1), Vida. Shakibi (1)

1. Physical Education and Sport Sciences School, Kharazmi University, Tehran, Iran

### INTRODUCTION

The foot is a relatively small base of support that maintains the body balance (Sandrey, 2008). A minor biomechanical alteration in this area may influence postural control (Hertel, 2002; Menz, 2005) and alter plantar pressure distribution (Ledoux, 2002; Pauk, 2010). On the other hand, postural dysfunction may result from genetical or environmental factors (Haber, 2006; Pajala, 2004). The purpose of this study was to assess the influence of foot type and heritability on static and dynamic balance and the plantar pressure distribution in female twins aged 18-35 years.

### METHODS

16 monozygotic (MZ) (mean mass  $52.92 \pm 8.73$  kg, mean height  $158.89 \pm 4.72$  cm, mean age  $23.81 \pm 3.31$  yr) and 14 dizygotic (DZ) (mean mass  $54.75 \pm 8.03$  kg, mean height  $159.64 \pm 4.38$  cm, mean age  $23.81 \pm 3.31$  yr) females twin pairs were included. The subjects had no history of injuries and were divided into three types: planus, rectus and cavus, by navicular drop test. The static balance was measured using strok stand test, in which the time of the stance was recorded while the subjects stood on the ball of the foot. The dynamic balance was measured using star excursion balance test, in which the participants performed 3 trials in each direction while balancing on the dominant leg. Plantar pressure distributions were measured by the emed-at platform for 5 steps of each foot using the two-step protocol at a self selected speed. Analysis has been done by two-way ANOVA, F test, Holzinger's heritability estimate ( $h^2$ ), Intraclass correlation coefficient and Fisher Z test (95% CI).

### RESULTS

No significant difference was found between the type of foot or zygosities in static and dynamic balance and plantar pressure distribution ( $P > 0.05$ ). Analysis of variances have revealed that there is no significant difference between within-pair variances of MZ and DZ twins ( $P > 0.05$ ) (Table 1). The Heritability has been estimated for the static and dynamic balance 0.43 and 0.39, respectively. However, there was no evidence that genetical factors influenced the plantar

pressure variable (Table 1). No significant difference was found in within-pair correlations ( $P > 0.05$ ).

Variables	S <sup>2</sup> DZ (n=14)	S <sup>2</sup> MZ (n=16)	F	h <sup>2</sup>
Static balance	28.57	16.16	1.77	0.43
Dynamic balance	46.16	28.26	1.63	0.39
Peak pressure (total)	11844.64	15167.40	0.78	-

Table 1: Within-pair variances, variance ratios (F) and heritability estimates of static and dynamic balance and plantar pressure distribution variables in MZ and DZ twins ( $P \leq 0.05$ ).

### DISCUSSION AND CONCLUSION

The finding of this study demonstrated that the foot type and zygosities did not influence balance or plantar pressure distribution. The present study results confirmed the previously results in relation to the effect of foot type on the measurement variables. These findings are, possibly, due to other compensatory motions or movement strategies, or both that allowed the subjects to overcome a deficit potentially due to foot type (Cote, 2005; Gribble, 2003; Hertel, 2002; Ledoux, 2002). Also, the results of heritability estimated in twin pairs were indicated as moderate genetical factors for balance maintenance. However, genetical factors demonstrated no influential role on plantar pressure distribution. More studies are needed in this field which could define the contribution of genetical or environmental factors in these variables and could help the experts in detecting them.

### REFERENCES

- Cote *et al*, J Athl Train 40:41-46, 2005.
- Gribble *et al*, Meas Phys Educ Exerc Sci 7:89-100, 2003.
- Haber *et al*, Am J Epidemiol 164:246-256, 2006.
- Hertel *et al*, J Athl Train 37:129-132, 2002.
- Ledoux *et al*, Gait Posture 15:1-9, 2002.
- Menz *et al*, J Gerontol 60:1546-1552, 2005.
- Pajala *et al*, J Appl Physiol 96:308-315, 2004.
- Pauk *et al*, Acta Bioeng Biomech 12:29-34, 2010.
- Sandrey *et al*, Med Sci Sports Exerc 40:449, 2008.



## Correlation of the golf handicap and the applied pressure values at the grasp of a golf club during teeing off

Stefan Lehner, Veit Senner

Technische Universität München, Institute of Ergonomics, Department Sport Equipment and Material, Boltzmannstraße 15, 85747 Garching, Germany

### INTRODUCTION

Golf is played by professionals and amateurs of all ages, genders, and skill levels (handicap). To evaluate a potential correlation of the handicap and the applied pressure values and positions detailed biomechanical analyses of pressure distributions at the grasp of a golf club during teeing off were carried out.

### MATERIAL AND METHOD

Measurements of pressure distribution at the grasp (at phalanges and metacarpals) of a golf club were carried out during teeing off. A grasp of a 3 wood club (PING, Phoenix, Arizona) was implemented with 48 pressure sensors (PAROMED, Neubeuern, Germany) and allowed a exact evaluation of forces acting at 12 positions of both hands.



Figure 1: Pressure sensors at the grasp of the golf club (left) Analyzed pressure areas at the left and right hand (right)

The analyses were carried out with golfers (right handers) with following handicap levels:

- Group 1: two professionals with handicap 0
- Group 2: two golfers with handicap 4-5
- Group 3: three golfers with handicap 14-15
- Group 4: one golfer with handicap 21

### RESULTS AND DISCUSSION

Fig. 2 shows the accumulated pressure values for left and right hand.

For all golfers with a handicap below 15 a very high reproducibility within the 3 swings was observed. As higher the handicap as higher pressures at the grasp of the dominant swing arm were observed.

Hosea & Gatt (1996) showed that professional players hit the ball with higher club velocities by using lower muscular loads compared to amateurs with higher handicaps.

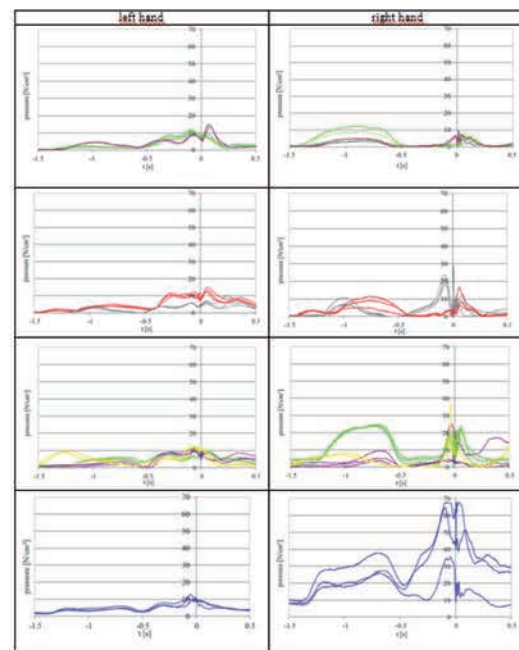


Figure 2: From group 1 (at the top) to group 4 (at the bottom): accumulated pressures at the left and right hand during hitting the golf ball (ball impact at 0 s)

During the professionals golf swings significant higher pressures were observed for the middle, the ring and the little finger of the left guiding hand. This corresponds to the observations of Kawashima & Nagata (1989).

### CONCLUSION

As better the handicap as lower forces applied by the right hand of the dominant swing arm were observed. Obviously professional players are able to carry out small corrections just before ball impact by a muscular of the hand of the guiding arm.

The evaluation of the applied pressure value and position can be used - in combination with a motion analyses and a pressure in the golf shoes - as helpful tool in golf training.

### REFERENCES

- Kawashima & Nagata, J Biomech 22:1035, 1989.  
Hosea & Gatt, Clin Sports Med 15:37-53, 1996

## CYCLING & IMPOTENCY: THE WAY FORWARD!

Nicholas. I. Cotton (1), Graham P. Arnold (1), Sadiq Nasir (1), Weijie Wang (1), Faisel Khan (2), Rami. J. Abboud (1)

- (1) Department of Orthopaedic and Trauma Surgery, Institute of Motion Analysis Research (IMAR), TORT Centre, University of Dundee, Scotland
- (2) Cardiovascular and Lung Biology Centre, Ninewells Hospital & Medical School, University of Dundee, Scotland

### ABSTRACT

**Introduction:** The activity of cycling is growing in popularity and presents a wide range of health benefits to those who use it as either a leisure activity or form of transport. However, there is an increasing awareness to the problems that the cyclist can suffer from as a result of from the interaction between the cyclist and the bicycle saddle. Saddle pressure can cause significant compression of the perineum, leading to compression of the underlying structures, specifically the blood vessels and nerves (Bressel *et al.* 2007). Soft tissue injuries, urogenital problems, altered perineal sensation, impotence and erectile dysfunction have all been implicated as a result of the bicycle saddle (Andersen and Bovim 1997, Jeong *et al.* 2002, Leibovitch and Mor 2005).

**Aims and Objectives:** The purpose of this study was to analyse two different bicycle saddle designs: a standard, traditional shaped saddle and a novel saddle named the Evolve, produced by Unified Sport. The study set out to compare the pressure exerted on each saddle due to rider weight, the blood flow to the medial thigh both before and after cycling and the perceived comfort of each saddle.

**Methods and Materials:** 20 male volunteers were recruited to the study. Each participant was required to test both the standard saddle and the Evolve saddle on a stationary bicycle for a period of six minutes per saddle, with a ten minute rest between cycling trials. Three blood flow measurements were taken per saddle using a Laser Speckle Contrast Imager; two of these measurements were taken pre-cycling, one whilst standing followed by another whilst sitting on the bicycle saddle, with the third measurement taken post-cycling whilst sitting on the saddle. During the cycling trial, participants completed a one minute warm up, followed by five minutes worth of pressure measurements per saddle. Pressure measurements over the saddle were taken using a Novel Pliance®-X-32 Expert system. A Visual Analogue Scale was used by the subjects to assess the expected comfort and experienced comfort of each saddle before and after use respectively.

**Results:** Pressure measurements have shown significantly lower mean pressure and mean force over all regions of the Evolve saddle compared to the standard saddle. Contact area on the Evolve was also significantly greater than the standard saddle in all regions. Peak pressure was significantly higher in all regions of the Evolve saddle, with the exception of the anterior perineal region where there was statistically no significant difference between saddles. There was also no significant difference between the saddles for either the static standing or the static sitting blood flow measurements taken pre-cycling. However, post-cycling measurements show the Evolve saddle to permit a significantly higher blood flow to all regions compared to the standard saddle. Although no statistical difference occurred in the expected comfort of the saddles, the Evolve saddle had a significantly lower experienced comfort compared to the standard saddle.

**Conclusions:** It is the unique design of the Evolve saddle that permits a lower saddle pressure and an increase in blood flow to the thigh when compared to a standard, traditional saddle. Although not perceived to be as comfortable as a standard saddle, the Evolve saddle is likely to have numerous advantageous to the health of the cyclist, especially in regard to the potentially serious problems that arise at the perineal area as a result of the saddle. It is possible that the Evolve saddle may bring about a change in the future of saddle design which has remained fairly constant since its inception with the bicycle.

### REFERENCES

- Andersen and Bovim, *Acta Neurol Scand* 95: 233-240, 1997
- Bressel *et al*, *J Biomech* 40:198-202, 2007.
- Jeong *et al*, *Int J Impot Res* 14:513-517, 2002.
- Leibovitch and Mor, *Eur Urol* 47:277-287, 2005.

## FIGURES



Figure 1: The standard saddle (left) and Evolve saddle (right) viewed from above.

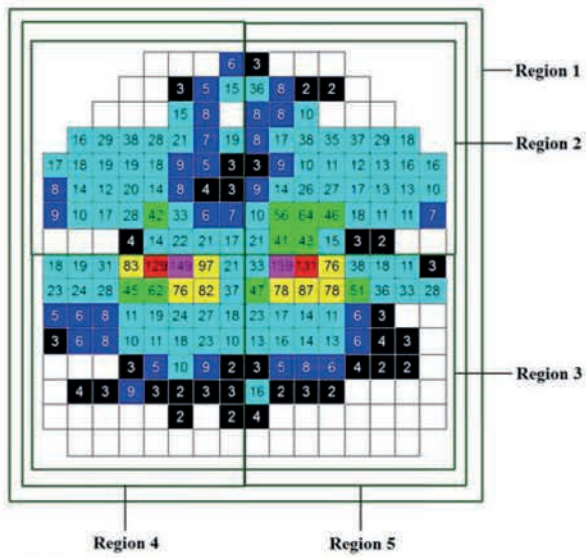


Figure 2: The five region mask applied to the pressure map.

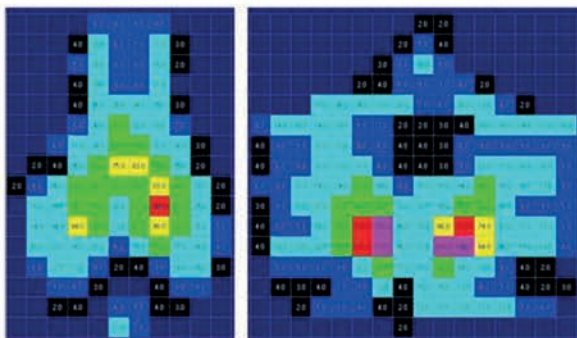


Figure 3: Pressure maps of the standard saddle (left) and the Evolve saddle (right).



## COMPARISON OF PLANTAR PRESSURE AND SHAPE CHANGES OF THE FOOT BETWEEN NORMAL WALKING AND WALKING WITH LIFTED SWINGING LEG

Bettina Fritz, Lisa Knorr, Stefan Grau

Medical Clinic, Department of Sports Medicine, University of Tuebingen,  
Hoppe-Seyler-Strasse 6, 72076 Tuebingen, Germany

### INTRODUCTION

Foot shape deforms under different loading situations (Xiong, 2009). Only few studies try to verify this generally accepted assumption during natural walking (Coudert, 2006; Kouchi, 2009; Schmeltzpenning, 2009). Knowledge of foot deformation is important to improve the fit of shoes. New approaches of dynamic foot scanning are promising but still provide incomplete results due to limitations of each technique. Synchronized camera systems capture 3D foot morphology while walking. Even if these cameras are well positioned, there are missing data because of the swinging leg. Therefore, it is possible to misinterpret foot measures during the stance phase. The aim of the present study is to demonstrate that the swinging leg is responsible for missing data. The second aim is to identify plantar pressure changes between walking with a lifted swinging leg and normal walking. Subsequently, we intend to find associations between changes of plantar pressure and foot shape..

### METHODS

We measured 33 subjects (♀ 17, ♂ 16) with mean age of  $25 \pm 9$  years and mean BMI of  $21.5 \pm 2.7$  kg/m<sup>2</sup>. After several test runs, we captured three trials during normal dynamic walking and another three during walking with the swinging leg lifted to about 90° knee angle. Walking speed was specified and adjusted to body height. All subjects walked over a 4.6 m walkway which contains a dynamic 3D scanner system and a pressure distribution platform. The scanner system DynaScan4D comprises five synchronized Digital Light Projection (DLP) scanner units (ViALIX, Germany), each composed of one Charge-Coupled Device (CCD) camera and one projection unit (Schmeltzpenning, 2009). This configuration captures the foot in motion at 46 Hz. We calculated seven foot measurements: MFK1- and MFK5-length, anatomical ball width, orthogonal heel width, anatomical ball girth, technical ball girth, and instep height, both at 62% of foot length.

To evaluate plantar pressure distributions we used an Emed-Platform (Novel GmbH, Munich) with a sample rate of 100 Hz. Maximum plantar pressure and force-

time-integral were analyzed in nine masks (Maiwald, 2008). Differences between the two walking situations were quantified using dependant t-tests ( $\alpha < 0.05$ ).

### RESULTS

Foot deformations were statistically significant in all measures between the two walking situations. These deformations are universal for instep height; for all other measures they are limited to different time periods of stance phase. Maximum plantar pressure as well as force-time-integral increased in all masks but the "hallux" with lifted swinging leg. There was a positive association between instep height and maximum plantar pressure during stance phase.

### DISCUSSION

Statistically significant foot deformations mainly resulted from missing data caused by the swinging leg during normal walking. Only instep height shows universal differences of about 1 mm. When comparing curves of normal walking and walking with lifted swinging leg, no incursion during stance phase was visible when lifting the swinging leg. Therefore, we conclude that an interpolation is possible. Walking with a lifted swinging leg does change plantar pressure distributions. Maximum plantar pressures increased equally in all masks except „hallux“. We conclude that the pattern of walking is the same in both situations, although overall more pressure takes effect. The offset at the end of stance phase seems to be unaffected. Increased maximum plantar pressure does not impact foot deformations, although instep height is higher. However, those deformations that could be explained by lifting the swinging leg were marginal and have no practical relevance.

### REFERENCES

- Coudert *et al*, 9<sup>th</sup> International Symposium on the 3D Analysis of Human Movement, 2006.
- Kouchi *et al*, GaitPosture 30 (4): 482-486, 2009.
- Maiwald *et al*, AppliedBiomech 24: 14-23, 2008.
- Schmeltzpenning *et al*, FootwearScience 1: 28-30, 2009.
- Xiong *et al*, AnthropologicalScience 117: 77-88, 2009.

## DOES FOOT TYPE AFFECT STRESS DISTRIBUTION IN THE FIRST METATARSOPHALANGEAL JOINT?

Rajshree Mootanah (1, 4), Antoine Truchetet (2, 4), Smita Rao (3), Cary Chapman (3),  
Ravinder R Regatte (3), Howard J Hillstrom (1, 4)

1. Hospital for Special Surgery, New York, USA
2. Université Henri Poincaré, Nancy, France
3. New York University, New York, USA
4. Anglia Ruskin University, Essex, UK

### INTRODUCTION

Osteoarthritis (OA) within the first metatarsophalangeal joint (MTPJ), is the most common form of degenerative joint disease in the foot (Horton et al., 1999) and causes debilitating pain. Many foot pathologies are of a biomechanical nature and often associated with one foot type over another (Wilder et al., 2005). OA is postulated to be the result of elevated stress within the involved joint. However, the link between 1st MTPJ stress and foot type is not known.

Excessive stress may be the most significant factor towards the onset and progression of OA. To our knowledge, no study has looked at the effect of foot type on 1st MTPJ stress employing physiological loading conditions for each foot type. Therefore, the aim of this study was to investigate the effect of different foot types on 1st MTPJ contact stresses at the mid-stance phase of gait, using FE methods.

### METHODS

A high resolution 7 Tesla MRI was used to create a geometrically accurate 3D model of the first MTPJ, using Mimics v14 imaging software (Materialise, Belgium). We simulated different 1st MTPJ declination angles (between the midshaft of the 1st metatarsal and the ground) to emulate different foot types (Erdemir et al., 2006). Planus, rectus, and cavus feet were represented by declination angles of 10.1°, 20.2°, and 30.7° (Goske et al., 2006), respectively. We employed the non-manifold assembly technique to create a perfect fit between bone and cartilage. This model was exported to ANSYS v12 FE package (ANSYS, Canonsburg, PA), where we applied material properties (Luo et al., 2011) and boundary conditions, representing the double support stance phase of gait. The ligaments were represented by spring elements. Adjacent elements corresponding to bones, cartilage and ligaments were tied to represent perfect bonding. The base of the first metatarsal bone was mechanically grounded (Figure 1). Plantar loading conditions were applied, based upon empirical plantar pressure data collected from 61 asymptomatic individuals with different foot types, walking across a Novel emed-x plantar pressure measuring system (Novel GMBH, Germany). FE analyses were run to predict stress in the 1st MTPJ for different foot types.

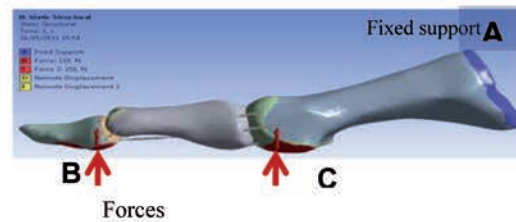


Figure 1: Computersimulation of a 1st metatarsal ray with boundary conditions: plantar forces (B and C) and mechanically grounded 1st metatarsal base A.

### RESULTS AND ANALYSIS

Results of our quasi-static 3D FE model during the mid-stance of gait yielded peak stresses in the distal 1st MTPJ cartilage of  $1.1 \times 10^6$  Pa,  $6.0 \times 10^5$  Pa, and  $9.7 \times 10^5$  Pa for planus, rectus, and cavus foot types, respectively (Figure 2). This corresponds to 83.3% and 61.6% increases in 1stMTPJ contact stress for the planus and cavus feet relative to the rectus foot.

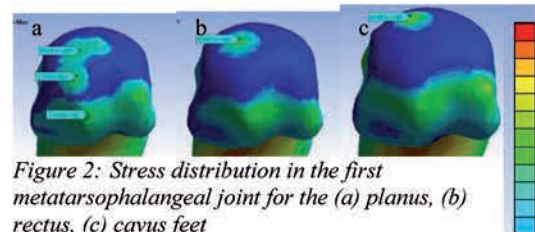


Figure 2: Stress distribution in the first metatarsophalangeal joint for the (a) planus, (b) rectus, (c) cavus feet

### DISCUSSION

Our results suggest that foot type plays a role in the pathomechanics of OA and that further work is warranted. This could explain the high occurrence of 1st MTPJ OA in the planus foot, further understanding of 1st MTPJ pathomechanics and inform clinicians of the elevated stress predicted in planus and cavus feet, which has implications for prevention and treatment of 1st MTPJ OA.

### REFERENCES

- Erdemir et al., J Biomech. 2006; 39(7): 1279-1286  
Goske et al., J Biomech. 2006; 39(13): 2363-2370  
Horton et al, Foot Ankle Int. 1999; 20(12): 777-80  
Luo et al, J Biomech. 2011 May 17; 44(8): 1559-1565  
Wilder et al, Osteoarthritis Cartilage 200513(3): 211-5

### ACKNOWLEDGEMENTS

NIH grant 1R03HD053135-01



## THE RISE OF MEANINGFULNESS – OR WHAT TO DO WHEN COMPLEXITY SURPASSES HUMAN INTELLIGENCE

Anne Skare Nielsen, [asn@futurenavigator.dk](mailto:asn@futurenavigator.dk), Future Navigator

1. Chief Futurist, Future Navigator, Biologist and Master of Political Science.
2. Guest lecturer IESE Business School, CBS. Alumni Wharton and Columbia
3. Member of the Chaos Pilots' pedagogical council, Unicef Denmark's presidium, Women on Board and advisory board member at Leaderlab.com, the Organic Company and People & Defence. She is member of the board at The Innovation Highschool, a former member of the Danish Ethical Council, and the Danish Science Ministry's ICT-forum.

### FROM MORE TO BETTER

That the world becomes an increasingly complicated place is not new. Complexity is what we call a linear megatrend that like a tsunami washes over us. In the coming years it will get even worse, which in practice means that we are in the process of creating a world that we are all too stupid to live in. Every time we start something new, we're bombarded with rules and regulations, documents and reports, meetings and analysis. Good research is drowning in bad research, scientist fake their research to get ahead, while the majority of citizen go on mental retirement. If you 20 years ago wanted to be a cleaning lady, you could go straight ahead. If you want the same thing today, you have to take numerous courses and learn about chemicals and lifting postures. Similarly, being a scientist is not the same today as 50 years ago. The amount of data and knowledge is increasing exponentially, and fortunately there will be plenty of technology to help us process data. With the use of algorithms and other smart software, research that currently takes months in the near future will take minutes. In IT they call it data mining. We call it meaning mining. Being able to make sense of complex stuff will be the prime criteria for success in the future. This puts new demands on our ability to cooperate, think holistically, tolerate irritation and provocation, to go into each other's disciplines, and to use reality as a sparring partner - also in relation to ask the meaning is relative to our fellowmen. Success is no longer "more". Not to reach a lot of things that produce a lot of data, writing a lot of articles, sell a lot of things, etc. Success is "better": creating and measuring quality. Break the limits and do something different. Experiment and evolve. Set the bar high and get a peace of mind. Always do the better thing.

### WHO WILL SUCCEED

Those who did well in the old MORE-paradigm, were those who could endure large doses of boredom. Those who could sit still for a long time, who could say no to beer and parties for exams, those who could endure long boring marathon meetings with uninspiring bosses and un-engaging visions, while producing a lot of junk that the world indeed does not

need - without ever asking themselves the question - why? Those who succeed in the new BETTER-paradigm are still those who can endure - but now enduring complexity. Being able to ask "what's the point?, What's the meaningfulness of this?". Be curious and constantly seek new puzzle pieces to a big picture that no one can complete alone. Those who can think holistically and cooperate, those who share and listen those who seek out irritation and frustration, will be the winners of tomorrow

### LISTEN LOUDER

The era of analysis is coming to an end. Analysis means taking things apart. The future requires something better. A less mechanic and more organic mindset, less ego and more wisdom, and less pleasuring and more happiness. There is more to science than understanding stuff and peer review. Science can't succeed by adding to complexity. We need to reduce complexity and "listen louder": What is the meaningfulness of what you do? How do you create value? How do we encourage a new generation to follow in the footsteps of science? The purpose of this generation might be - not to come up with more stuff - but to use what we've got in a better way.

### MEGATREND MODEL



futurenavigator

Figure 1: Megatrends

Model + videos at [www.futurenavigator.dk](http://www.futurenavigator.dk)



## THE EFFECTIVENESS OF OFFLOADING-IMPROVED CUSTOM FOOTWEAR ON PLANTAR FOOT ULCER RECURRENCE IN DIABETES: A MULTICENTER RCT

Sicco A. Bus (1,2), Mark L.J. Arts (1), Roelof Waaijman (1), Mirjam de Haart (1), Tessa Busch-Westbroek (1), Sijf G. van Baal (2), and Frans Nollet (1)

1. Department of Rehabilitation, Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands
2. Department of Surgery, Ziekenhuisgroep Twente, Almelo, the Netherlands

### BACKGROUND

Custom-made footwear is commonly prescribed to diabetic patients to prevent foot ulceration, but the evidence to support its use is still meager. This is probably because offloading efficacy is often not known, and footwear designs have variable effects. Therefore, an individualized approach where in-shoe pressure analysis is used as guidance tool for footwear modifications may be needed. A 17-52% reduction in peak pressures can be achieved with this approach, and may be an effective method to reduce ulcer risk (Bus et al. 2011). Therefore, the aim was to assess the effectiveness of custom-made footwear, of which offloading was improved based on in-shoe plantar pressure analysis, in preventing plantar foot ulcer recurrence in high-risk diabetic patients.

### METHODS

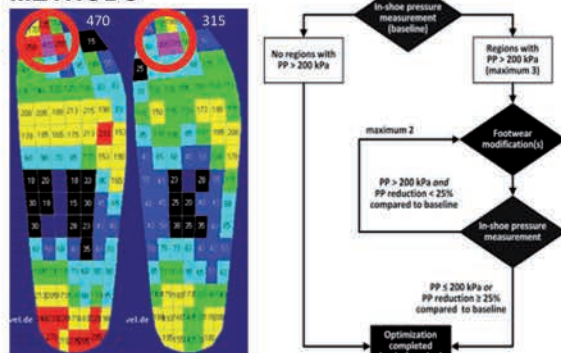


Figure 1: Protocol for offloading improvement

In a multicenter randomized controlled trial, 171 persons with diabetes, neuropathy, and a recently healed plantar foot ulcer were randomized to either footwear of which the offloading properties were improved and preserved over time by modifying the footwear at delivery and at 3-monthly follow-up visits based on in-shoe pressure analysis using Pedar-X (intervention group, Figure 1) or footwear that was evaluated based on current practice (control group).

In an intention-to-treat analysis, the primary outcome was ulcer recurrence rate in 18 months. In

secondary analysis, we assessed ulcer classification, dynamic barefoot pressures (Emed-X), footwear adherence measured using shoe-worn sensors (@monitor), and daily step count measured using an ankle-worn activity monitor (StepWatch).

### RESULTS

In-shoe maximum peak pressures measured over time were ~20% lower in the intervention group than in control. Dropout rate was 6%. The 18-month ulcer recurrence rate was 39% in the intervention group and 44% in the control group ( $p=0.48$ , OR: 1.25, 95%CI: 0.68-2.30). Ulcer free survival was not significantly different between groups ( $p=0.41$ ). Significantly less complicated ulcers (Texas grade 3 or C,D) were found in the intervention group compared to control (0 vs 6,  $p=0.02$ ). Mean barefoot peak pressure distal to the heel was 896 kPa for the intervention group and 954 kPa for control ( $p=.06$ ). Mean daily step count was 7113 for the intervention group and 5936 for control ( $p=.004$ ). Mean footwear adherence was 67% for the intervention group and 76% for control ( $p=.07$ ) and was lower while at home.

### DISCUSSION

Offloading-improved custom-made footwear (~20% peak pressure relief) did not reduce plantar ulcer recurrence rate compared to non-modified custom-made footwear in patients at high risk for ulceration. It did reduce ulcer severity, although numbers were small. Plantar pressure relief and improvement, whether or not based on measures of in-shoe pressure, may still be important, in prevention, but more pressure relief may be required to be effective. Alternatively, other factors, such as frequent repetitive cycles of walking unprotected on a deformed foot with high barefoot pressures may counteract any beneficial offloading effect in explaining the high recurrence rates found. Prevention may require a more comprehensive analysis of factors, including offloading footwear, education, and early recognition of pre-ulcerative lesions.

### REFERENCES

Bus et al., 2011. Diabetes Care 34: 1595-1600

## INFLUENCE OF PHYSICAL THERAPY INTERVENTION ON FOOT ROLLOVER PROCESS DURING GAIT OF DIABETIC NEUROPATHIC PATIENTS

Cristina D Sartor, Ricky Watari, Anice C. Pássaro, Andreja P. Picon, Renata HH Vilibor, Isabel CN Sacco

Physical Therapy, Speech and Occupational Therapy Dept., School of Medicine, University of Sao Paulo, Brazil

### INTRODUCTION

The feet are the main target of biomechanical, sensorial and motor complications that predispose patients with diabetic polyneuropathy (DPN) to foot rollover process alterations. Tissue alterations due to non-enzymatic glycosylation can result in foot rigidity, which alter proper segmental foot mobility and adequate foot rollover during gait<sup>1,2</sup>. Weakness of the intrinsic foot muscles is also prevalent in this population<sup>3</sup> and contributes to ROM restriction and to poor dynamic stability of the foot, especially to maintain the longitudinal arch. All these losses lead to poor capacity of load absorption by the foot and ankle and to an increase in plantar pressures in patients with diabetes<sup>1,2</sup>, predisposing them to plantar ulcers<sup>4</sup>. Assuming that functional recoveries of ROM and muscle weakness are possible, the aim of this study was to investigate the effect of a kinesiotherapy intervention on foot rollover process during walking of individuals with DPN. This intervention aimed at increasing ROM, foot and ankle muscle strength and improving functional training of gait.

### METHODS

This is a randomized controlled trial (ClinicalTrials.gov Identifier: NCT01207284), where twenty-six diabetic neuropathic patients were randomized in Control Group (CG - 58±4 yrs, 18±8 yrs Diabetes, 30±7 kg/m<sup>2</sup>, fasting glycaemia 196.1±99.62 mg/dl) or Intervention Group (IG - 58±4 yrs, 18±11 years Diabetes, 27±4 kg/m<sup>2</sup>, fasting glycaemia 162.2±60.48 mg/dl). Peak pressure (PP), pressure-time integral (PTI) and contact area (CA) (Pedar X system, Novel) were analyzed during walking in 6 areas: heel, midfoot, lateral and medial forefoot, hallux and toes. Time series analysis were analyzed to measure the time to peak pressure (TPP) throughout the same 6 areas, time normalized by 0-100% of stance phase. The intervention protocol is detailed somewhere else<sup>5</sup>. Flexion and extension of ankle were measured with a goniometer. Foot intrinsic and extrinsic muscles function were measured with manual testing. The difference between baseline condition and after 12 weeks were calculated and compared between groups for all variables. The differences are described as effect sizes (Cohen's d coefficient) and p-values of T-test for independent measures.

### RESULTS

Although ROM and muscle function presented a small effect of the intervention, plantar pressure variables showed important intervention effects. There was an increase in heel CA (p=0.13, Cohen's d=0.45) and a delayed TTP at the heel

(p=0.18, Cohen's d=0.44). There was a moderate effect of increase in PTI at midfoot (p=0.08, Cohen's d=0.52), lateral forefoot (p=0.02, Cohen's d= 0.67) and toes (p=0.15, Cohen's d=0.42). The TPP at medial forefoot was anticipated after the intervention (p=0.03, Cohen's d=0.79). There was a moderate increase in the hallux CA (p=0.26, Cohen's d=0.43), hallux PTI (p=0.05, Cohen's d=0.57) and hallux PP (p=0.06, Cohen's d=0.55). The gait speed were not different between groups (p>0,05).

### DISCUSSION

The intervention improve the foot rollover process during gait which was reflected in the redistribution of plantar pressures. An important effect was the delayed time to peak pressure at the heel, that could represent a soften heel strike. It may suggest a better eccentric muscle control of the ankle flexors at the heel strike phase. The heel position in the initial contact can affect the rest of the foot behavior during the stance phase, and a proper alignment and control of this segment would avoid overloading other foot areas. DPN patients usually present a shorter excursion of center of pressure<sup>6</sup> during gait, indicating almost absence of toes and hallux participation. After the intervention, these two areas showed an increase in its participation in stance phase, reflected by their PTI and PP increase, suggesting a toe off more pronounced. A proper toe off indicates that the foot propels the body forward with an inverted position, considered the normal foot rollover dynamic alignment. The increase in PTI at the midfoot and lateral forefoot also indicate a more normal pattern of foot dynamic alignment, since the foot rollover should have an excursion through these areas.

### CONCLUSION

Even with no effect of intervention in the segmental ROM and muscle function, the plantar pressure suffered important effects towards a more effective foot rollover. The exercises, associated with gait training, could have promoted a motor learning that was sufficient to change plantar pressures.

### REFERENCES

1. Giacomozzi & Martelli, *Gait Posture*. 2006; 23(4):464-470.
2. Rao *et al*, *Gait Posture*. 2006; 24(3):295-301.
3. Bus *et al*, *Diabetes Care*. 2002. 25:1444-1450.
4. Zimny *et al*. *Diabetes Care*. 2004; 27(4):942-946.
5. Sartor *et al*, *BMC Musculoskelet Disord*. 2012 Mar 19;13(1):36.
6. Giacomozzi *et al*, *Diabetes Care*. 2002 Aug;25(8):1451-7.



## THE EFFECT OF STRENGTHENING EXERCISES ON GAIT BIOMECHANICS IN PATIENTS WITH DIABETIC PERIPHERAL NEUROPATHY

Alejandro Meana-Esteban, Patricia Price, Robert. W. M. van Deursen

Research Centre for Clinical Kinaesiology, School of Healthcare Studies, Cardiff University.  
Correspondence to: [vanDeursenR@cardiff.ac.uk](mailto:vanDeursenR@cardiff.ac.uk); [Meana-EstebanA@cardiff.ac.uk](mailto:Meana-EstebanA@cardiff.ac.uk)

### INTRODUCTION

Physical activity, due to its physiological benefits, is considered essential in the treatment of diabetes. In subjects with diabetic peripheral neuropathy (DPN) foot ulcer risk must also be considered.

Muscle weakness and sensory neuropathy (SN) are known to influence gait in DPN subjects, including spatial-temporal characteristics and foot function. The aim was to investigate the effect of strength training on these outcome measures; also in relation to changes in foot pressures, which are considered a risk factor for foot problems in patients with DPN.

### METHODS

Forty two patients with DPN without severe foot deformities were included in the study (mean age  $62.85 \pm 6.97$ ) of which 21 belonged to an exercise (EXE) group and 20 to a control (CON) group.

The exercise programme consisted of twice-weekly 16 weeks of low weight bearing strengthening exercises with measurements PRE and POST intervention. Gait velocity (GV) was used to investigate gait characteristics whereas arch index, velocity of the COP (COPvel) and lower limb muscular activity patterns [measured with electromyography (EMG)] were used to investigate foot function. Peak pressures (PP) were measured with an EMED platform at the heel (HE), metatarsal (MT) and hallux (HA) regions. Lower limb muscle strength and SN were also measured. Group\*Time interaction was investigated using a two-way mixed ANOVA.

### RESULTS

No significant group differences over time were observed in GV ( $p=0.818$ ). COPvel at the HE was the only foot function outcome measure that reached significance ( $p=0.047$ ). EMG in the Tibialis Anterior (TA) during heel strike showed a trend ( $p=0.058$ ) toward higher values over time in the EXE compared to the CON group. Group differences in PP over time were only significant at the HE ( $p=0.017$ ).

	CON Group		EXE Group	
	PRE	POST	PRE	POST
<b>GV (ms)</b>	1.11±0.16	1.11±0.15	1.16±0.21	1.16±0.19
<b>Arch Index</b>	0.19±0.07	0.19±0.08	0.21±0.05	0.20±0.06
<b>EMG TA %</b>	76.92±7.63	68.20±13.45	72.97±14.35	74.53±12.37
<b>COPvel HE(ms)</b>	0.44±0.12	0.45±0.10	0.50±0.10	0.46±0.09*
<b>PP HE (kPa)</b>	475.05±196.40	454.33±198.23	439.57±90.19	463.42±124.97*
<b>PP MT (kPa)</b>	852.55±260.93	826.88±266.31	765.11±281.85	774.35±282.30
<b>PP HA (kPa)</b>	522.33±351.79	505.83±342.15	489.89±290.57	525.15±329.15
* Significant Group*Time interaction $p<0.05$				

Figure 1: Changes in gait biomechanics over time.

Surprisingly, muscle strength did not change over time when comparing both groups ( $p>0.115$ ) whereas SN improved significantly in the EXE group ( $-3.12V$ ) compared to the CON group ( $+1.42V$ ) ( $p=0.027$ ).

### DISCUSSION

These findings suggest that the benefits of exercise are less biomechanical and more physiological in nature. Nevertheless, the results suggest some changes over time in foot function. It is possible that changes in TA EMG activity during heel strike may have led to a more controlled foot drop (slower COPvelHE), and to a higher PP HE (i.e. more dorsiflexion) in the EXE group POST. Interestingly, the intervention influenced the progression of SN. Improved sensation may play a positive role in the prevention of foot ulcers.

These results suggest that strength training may be safely recommended in DPN subjects since it did not augment the risk of foot ulcers related to changes in gait biomechanics while triggering beneficial physiological adaptation, including in sensation.



## MIDSOLE GEOMETRY AFFECTS PLANTAR PRESSURE PATTERN DURING WALKING IN DIABETIC FOOTWEAR

Bjoern Braunstein (1,2), Stephen Preece (3), Jonathan Chapman (3), Angela Hoehne (2), Christopher Nester (3), Gert-Peter Brüggemann (2)

1. German Sport University Cologne, Institute of Biomechanics and Orthopaedics, Germany
2. German Research Centre of Elite Sport, Cologne, Germany
3. School of Health, Sport and Rehabilitation Science, University of Salford, United Kingdom

### INTRODUCTION

The most commonly prescribed shoe for diabetic type II patients is the rigid rocker shoe. It is accepted that these kinds of rocker shoes are able to reduce in-shoe plantar pressures in order to minimize the risk of ulceration in diabetic patients. However, the efficiency of the three principal design features of a traditional rocker shoe (apex position, rocker angle and apex angle, see Figure 1) is not systematically understood. Only one known study with healthy subjects (van Schie, 2000) to date has systematically varied two of the three mentioned midsole design features.

### METHODS

By using twelve different curved rocker shoe designs and a control shoe (all with the same shoe upper), we systematically varied each design feature apex position (50% - 70% of shoe length), Rocker angle ( $10^\circ$  -  $30^\circ$ ) and apex angle ( $70^\circ$  -  $100^\circ$  to longitudinal shoe axis). For each shoe 1<sup>st</sup> metatarsophalangeal joint (MPJ) pressure was measured during walking. Data was collected from 30 diabetic and healthy subjects and repeated measures ANOVA used to investigate the mean effect of each footwear feature. Descriptive statistics were used to investigate inter-subject variability and a two-way ANOVA was used to compare the response between the diabetic and healthy cohort.

### RESULTS

All three design features (rocker angle, apex angle, apex position) had a significant effect on peak 1<sup>st</sup> MPJ plantar pressure. However, there was considerable inter-subject variability in the optimal rocker angle and optimal apex position. In contrast, an apex angle of between  $90^\circ$ - $100^\circ$  resulted in minimal plantar pressures across almost all diabetic subjects.

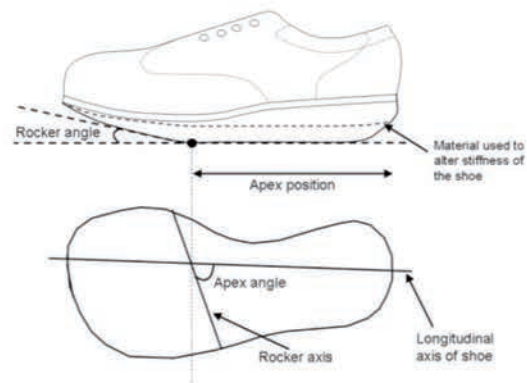


Figure 1: Schematic description of the three (rocker angle, apex angle, apex position) most varied principal design features of traditional/curved diabetic footwear.

### CONCLUSION

The results suggested that plantar pressure off-loading can be achieved by employing an apex angle of approximately  $95^\circ$ .

However, rocker angle and apex position should be chosen on individual by individual basis.

### REFERENCES

van Schie C, Ulbrecht JS, Becker MB, Cavanagh PR: Design criteria for rigid rocker shoes. *Foot & Ankle International* 21(10), 833-844, 2000

### ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Community's Seventh Framework Program (FP7 / 2007-2013) [2007-2011] under grant agreement No. [NMP2-SE-2009-229261].

## PLANTAR PRESSURE DURING GAIT IN DIABETIC NEUROPATHY: EFFECT OF SEVERITY DEGREE CLASSIFIED BY A FUZZY EXPERT MODEL

Adriana N. Hamamoto (1), Ricky Watari (1), Lucas Tonicelli (1), Cristina D. Sartor (1), Neli R. S. Ortega (2), Isabel C. N. Sacco (1)

1. Physical Therapy, Speech and Occupational Therapy dept., School of Medicine, University of Sao Paulo, SP, Brazil
2. Center of Fuzzy Systems in Health, School of Medicine, University of São Paulo, São Paulo, SP, Brazil

### INTRODUCTION

The co-existence of diabetic sensorimotor polyneuropathy (DSP) and high plantar pressures has been related to ulcerations and amputations (Veves *et al*, 1992), but these foot loading alterations seem to be present even in the absence of neurological impairment (Pataky *et al*, 2005). This could be happening because of inconsistencies on disease diagnosis and classification. DSP has unclear and subjective sickness-health boundaries, lacking definition on diagnostic and classification methods, which may lead to inconsistencies in biomechanical findings. The Theory of Fuzzy Sets can be a useful method for classifying patients, since it takes into account inherent uncertainties in the clinical assessment of diabetes and DSP. The aim of this study is to investigate the effect of DSP severity degree, classified by a Fuzzy Expert Model, on the plantar pressure distribution during gait.

### METHODOLOGY

98 subjects were divided into 4 groups: 29 diabetic individuals without DSP (D); 39 with mild (MiN); 15 with moderate (MoN), and 15 with severe neuropathy (SN). The input data for the Fuzzy System (Picon *et al*, 2012) were DSP symptoms and signs, assessed with the Michigan Neuropathy Screening Instrument questionnaire and physical assessment, diabetes duration and glycemia levels. Subjects were equipped with Pedar-X insole system and walked over a 10 meter walkway, wearing anti-skid socks. Peak pressure, contact area and pressure-time integral were acquired at 100Hz in heel, midfoot, lateral and medial forefoot and hallux. Statistical analysis was performed with Kruskal-Wallis ANOVA test and Mann-Whitney test (post hoc test).

### RESULTS AND DISCUSSION

All groups with DSP had significantly higher peak pressures (kPa) than D at the heel (D-264.4±67.5, MiN-319.3±92.3, MoN-312.4±83.2, SN-291.9±75.2) and medial forefoot – except for MiN at this site – (D-258.9±63.9, MiN-225.6±93.1, MoN-295.6±81.9, SN-287.2±86.5). At lateral forefoot only MoN and SN were different (D-281.6±81.5, MiN-277.0±94.6, MoN-343.9±101.6, SN-

327.5±98.3). Pressure-time integral (kPa.s) at the heel was higher for MiN and MoN (D-76.7±43.1, MiN-78.5±49.4, MoN-84.3±36.7, SN-71.53±26.0), and at lateral and medial forefoot D had lower values (lateral: D-83.0±25.2, MiN-85.2±51.7, MoN-102.0±36.2, SN-97.9±35.9; medial: D-78.7±17.8, MiN-76.4±51.3, MoN-90.2±26.6, SN-87.6±29.0). Even at early stages of DSP, there seems to be higher loads, which is an important risk factor for plantar ulceration (Fryberg *et al*, 1998). Studies show that diabetes itself may cause muscle cells dysfunction (Wang *et al*, 2006) and higher plantar pressures during gait, which was confirmed with our results.

DSP groups displayed higher peak pressures at the hallux, although it was only significant for MoN (D-188.1±96.9, MiN-195.6±98.1, MoN-244.1±106.1, SN-203.6±85.0). Reduced mobility of the metatarsophalangeal joint (Sacco *et al*, 2009), may lead to higher loads at this foot site. Though gait velocity was not controlled, a possible intervenient factor, literature states that diabetic subjects with DSP walk slower (Dingwell *et al*, 2000), but, even so, foot loads were higher, indicating that there is an influence of sensorimotor loss or tissue alterations, characteristic of the disease.

The fuzzy expert model was successful at classifying this population and enabled the identification of the moment when plantar pressure alterations begin. This could be helpful at determining interventions at early stages of the disease.

### CONCLUSION

Pressure patterns start to suffer alterations at early stages of DSP and even without the presence of DSP, with further aggravation with the progression of the disease. Fuzzy expert system is a useful tool for a better distinction of DSP severity degree.

### REFERENCES

- Dingwell *et al*, Gait Posture 10:21-9, 2000.
- Fryberg *et al*, Diabetes Care 21:1714-9, 1998.
- Pataky *et al*, Diabet Med 22:762-7, 2005.
- Picon *et al*, Clinics 67:151-6, 2012.
- Sacco *et al*, Clin Biomech 24:687-92, 2009.
- Veves *et al*, Diabetologia 35:660-3, 1992.
- Wang *et al*, Endocrinology 147:4160-8, 2006.



## INFLUENCE OF MUSCLE FORCES ON LOAD DISTRIBUTION IN THE KNEE

Wolfgang Potthast (1, 2), Karsten Engel (2), Kai Heinrich (2), Jens Dargel (3), Gert-Peter Brüggemann (2)

1. BioMotion Center, Department of Sport and Sport Science, Karlsruhe Institute of Technology, Germany
2. Institute of Biomechanics and Orthopedics, German Sport University Cologne, Germany
3. Department of Orthopedic and Trauma Surgery, University of Cologne, Germany

### INTRODUCTION

The progression of gonarthrosis is strongly related to the medio-lateral distribution of joint load (Roos et al., 2010; Andriacchi et al., 2004). In the talocrural joint muscle forces have the potential to redistribute joint contact stress by tension banding without changing the joint angles (Potthast et al., 2008). The human knee joint however has less bony and ligamentous constraints. Also the line of action of crossing muscles differs substantially from those (tibialis posterior, flexor hallucis, flexor digitorum) affecting the joint contact stress in the talocrural joint. This study aims to study the effect of knee muscles on the distribution of joint load, considering their influence on joint angle changes.

### METHODS

Six fresh frozen knee cadavers were freed of skin and subcutaneous soft tissue. The knee capsule, shafts of tibia and femur were kept. The proximal tendons and muscle tissue of the lateral muscle group including gastrocnemius and vastus lateralis (GL, VL), biceps femoris (BF) and the medial muscle group including gastrocnemius and vastus medialis (GM, GL) and semitendinosus (ST) were connected to metal sheaths. The sheaths were connected to pneumatic actuators, which applied defined forces (225N). The ends of the femur and tibia were mounted to a custom made knee simulator (figure 1). A pressure sensor mat (pliance S2015 kneepad, novel) specified for measuring joint load in the knee was inserted between tibia and femur.

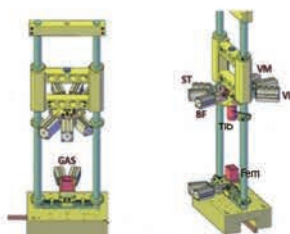


Figure 1: Knee simulator with pneumatic actuators for muscle force simulation. Tibia and femur fixations are indicated (Fem, Tib).

Marker arrays were connected to tibia and femur using intracortical screws. To quantify joint kinematics a

five camera system (Vicon Nexus) was used. To identify the effect of lateral and medial acting muscles on load distribution three sequences were defined: LAT: force application through the lateral muscle group; MED: medial muscle group; L+M: all muscles. To distinguish between the influences of muscular tension banding and muscular induced joint angle changes, all force sequences were applied with a free movable tibia as well as a fixated tibia to prevent from frontal and transversal knee rotation. To assess the medio-lateral load distribution a the ratio (medial force)/(lateral force) was calculated.

### RESULTS AND DISCUSSION

Muscle force simulation by the medial muscle group leads to knee adduction (3-6°), by the lateral to knee abduction (2-7°). It is obvious, that muscle forces have a big influence on the medio-lateral force distribution (figure 2). This is remarkably bigger in combination with knee angle changes in the frontal plane (black). But also under the fixated condition, where no knee angle changes occurred, a clear force re-distribution is obvious. The muscular tension banding effect on load distribution is clearly smaller in the knee joint compared to the talocrural joint (Potthast et al., 2008). This is probably due to different lines of action of the muscles. Clinical strategies with the aim of controlling joint load distribution might have to consider the line of action and joint morphology.

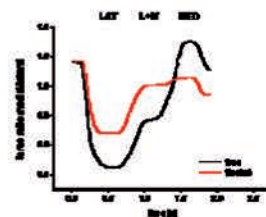


Figure 2: Time history of the force ratio. LAT: lateral muscles, MED: medial muscles, L+M: all muscles.

### REFERENCES

- Andriacchi et al., Annals of Biomedical Engineering 32: 447-457, 2004  
 Potthast et al., Clinical Biomechanics 23: 632-639, 2008  
 Roos et al., Nature, doi: 10.1038, 2010



## SQUAT MOVEMENT QUALITY QUANTIFIED BY PLANTAR PRESSURE DISTRIBUTION IN PATIENTS FOLLOWING TOTAL HIP ARTHROPLASTY

Torsten Brauner (1), Marion Zillober (1), Ernst Rämisch (2), Thomas Horstmann (1,2)

1. Conservative & Rehabilitative Orthopedics, Technische Universität München, Germany
2. Medical Park St. Hubertus, Bad Wiessee, Germany

### INTRODUCTION

The sit-to-stand or squat movement is a basic movement necessary for numerous everyday tasks e.g. sitting or climbing stairs [1]. In orthopedic rehabilitation, squats are commonly used as a functional exercise to train patients' limb strength and coordination. For diagnostic purposes, the quality of squat execution is estimated subjectively by therapists to evaluate therapy progress. Objective quality measures, however, are insufficient or impracticable up to this point. Pressure distribution measurements allow quantifying inter-limb weight distribution and the center of pressure (CoP) path objectively. It was hypothesized, that deficits in the squat execution, common in patients following total hip arthroplasty (THA) [2], manifest themselves in these variables.

Thus, the purpose of this study was to introduce a method to objectively quantify squat execution quality and to utilize it to document therapy progress of THA patients in a stationary rehabilitation setting.

### METHODS

The subject pool consisted of 61 THA-patients (34♂/27♀; 62±9yrs, 77±14kg, 174±9cm) and a reference group (REF) without acute limb pathologies (22♂/16♀; 47±12yrs; 78±20kg; 175±10cm). THA-patients were analyzed twice: 13.2±3.8 days (PRE) and 26.6±3.3 days post-surgery (POST).

Each measurement session consisted of two sets of five squats, performed at self-chosen movement speed, separated by a 1-min break. The lowest point of each squat was signaled when subjects touched a therapeutic chair that was adjusted so hip flexion never exceeded 90°. Pressure distribution was measured separately for each foot using two pressure mats (pedar® posturo, Novel, Germany). Data was recorded at 45Hz for 35s.

For each squat, the average inter-limb force distribution was determined. Root mean square of the CoP movement was calculated in anterior-posterior (RMS<sub>ap</sub>) and medio-lateral (RMS<sub>ml</sub>) direction for the operated (OP) and non-operated (NON) leg. Subjective perception regarding functionality was assessed using the FFb-H-OA 2.0.

Data of the first and last squat of each set were ignored; the parameters of the remaining six squats were averaged. Student t-test were used for PRE vs. POST comparisons (paired) and for THA-patients' POST measurements vs. REF (unpaired). Assessment scores were compared (PRE vs. POST) using the non-parametric Wilcoxon test. Alpha level was set to .05.

### RESULTS

The unloading of the OP by .10bw, present at PRE, was reduced at POST ( $p<.001$ ) and, thereby, did not differ anymore compared to REF ( $p=.250$ ). Similarly, RMS<sub>ml</sub> was reduced to the level of REF in both legs at the post-test (Fig. 1). However, RMS<sub>ap</sub> was not reduced between PRE and POST and, therefore, remained significantly higher than REF (Fig. 1). In the subjective assessment, 15 of 18 score items improved significantly between PRE and POST.

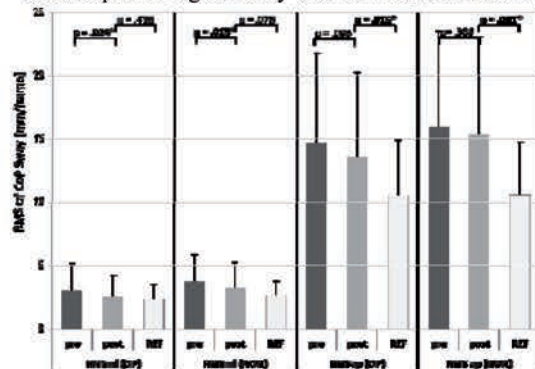


Figure 1: RMS<sub>ap</sub> and RMS<sub>ml</sub> for OP and NON ( $\alpha=.05$ ).

### DISCUSSION

Pressure distribution measurements of squats are useful to objectively monitor therapy progress and to reveal motion deficits. On this basis, we suggest that THA patients, for example, should focus more intensively on their ap-sway control.

### REFERENCES

- [1] Flanagan *et al.*, Med Sci Sports Exerc 35(4): 635-643, 2003.
- [2] Talis *et al.*, Clin Biomech 23(4): 424-433, 2008.

## FORCE AND PLANTAR CONTACT AREA CHARACTERISTICS DURING PUSH-OFF IN CROSS-COUNTRY SKIING.

Pavel. Korvas, Vladimír. Hellebrandt, Martin. Zvonar

Faculty of Sport Science, Masaryk university, Czech Republic

### INTRODUCTION

Performance in cross-country skiing is more and more influenced by the quality of strength abilities. Most propulsive forces are produced during cross-country skiing by lower extremities and the size of such forces is decisive in performance both in classic technique and skating (Komi 1987, Lindinger 1995, Rusko 2003). This descriptive study is concerned with the size of plantar vertical forces resulting from the push-off in various cross-country ski techniques. Another aim is to observe the size of plantar area during maximal vertical force.

### METHODS

Subjects: 3 experienced and well-trained cross-country skiers, top national level. Average age 20.5 ( $\pm 0.7$ ), height 180.8 cm ( $\pm 4.1$ ), weight 75.7 kg ( $\pm 5.3$ ). Instrumentation: capacitive pressure insoles in the shoe (Pedar Mobile, Novel Munich, 99 sensors, 50 Hz). Protocol: the skiers were skiing at the race speeds for 60 meters, the last 30 meters were monitored. Tests were carried out on the flat and the uphill (7°) part of track. Skiers were tested for 5 techniques: diagonal stride (DS), double poling with a kick (DPK), V1, V2, and skating without poling (SWP). Parameters: Maximal force (N), contact plantar area (cm<sup>2</sup>), vertical force in multiple of body weight (mBW). Statistics: average, percentage.

### RESULTS

In agreement with other studies, bigger vertical forces during push-off by the lower extremities were found in classic techniques (DS, DPK), whereas in skating techniques they were significantly lower. Maximal push-off vertical forces expressed in mBW (tab.1) were on average 1.5 times bigger in classic techniques than in ski skating. In techniques, where performance depends mainly on the quality of the lower extremities push-off (DS, SWP), the value of maximal vertical force in uphill part of track increased by a minimum value. In the other techniques, where the work of arms (double poling) contributes to propulsive forces significantly, lower values at push-off were found in uphill than in flat. When the size of maximal forces in flat and uphill areas for each technique is compared, only the decrease for V1 by 16.5 % can be considered as a significant difference. It has not been proved that the skier uses significantly bigger vertical force at the

push-off during the run uphill. This result confirms the growing importance of the arms performance for the production of propulsive forces in steeper hills, mainly in techniques which make use of double poling.

Techniq.	DS	DPK	V2	V1	SWP
Terrain	Fmax	Fmax	Fmax	Fmax	Fmax
Flat	1643	1638	1108	1064	1062
Uphill	1692	1580	1084	913	1083
Diff. %	3,0	4,7	2,2	16,5	2,0
Techniq.	V2	DKP	V2	V1	SWP
Terrain	mBW	mBW	mBW	mBW	mBW
Flat	2,2	2,2	1,5	1,4	1,4
Uphill	2,3	2,1	1,5	1,2	1,5

Tab.1 Size of maximal force (N) during kick and its multiple in body weight (mBW).

At the time of maximal vertical force, plantar contact area on insole during diagonal stride and double poling with kick was always larger than in skating techniques (tab. 2). The discovered differences in size of plantar contact area between skiing on a flat and uphill track in individual techniques was of a minimum value. The discovered differences in the size of plantar contact area at the time of maximal force between push-off on flat and uphill for all techniques can be considered insignificant.

	DS	DPK	V2	V1	SWP
Flat	66,2	58,6	42,9	44,7	45,3
Uphill	58,0	56,9	48,2	44,7	48,8

Tab.2 Percentage of plantar contact area from maximal sole area at the time of maximal push-off force.

### CONCLUSIONS

Despite intense effort and certain changes of body position during skiing uphill, the observed skiers did not produce bigger vertical force on the ski during push-off. Plantar contact area of the skier at the time of maximal force is not significantly different while running on a flat or uphill part of track.

### REFERENCES

- Komi *et.al*, Int.J. Sport Med. 8: 8, 48-54, 1987.  
Lindinger *et.al*, Leistungssport 25:2 45-49, 1995  
Rusko *et.al*. Blackwell Sci. 32 – 51, 2003.



## RELATIONSHIP BETWEEN MUSCLE SIZE AND TOE FLEXOR STRENGTH

Karen. J. Mickle (1,3), Salih. Angin (2), Gillian. Crofts (1), Christopher. J. Nester (1)

1. Centre for Health Sciences Research, University of Salford, United Kingdom
2. School of Physiotherapy and Rehabilitation, Dokuz Eylül University, Turkey
3. Biomechanics Research Laboratory, University of Wollongong, Australia

### INTRODUCTION

The ability to walk efficiently and safely is vital for older people to maintain their independence and avoid falling. As an individual's toes are in contact with the ground for 75% of the stance phase of gait, it is vital that we understand their role during walking and balance. It is believed that during gait the long toe flexor muscles help control forward progression of the leg over the foot and hold the toes on the ground, while the intrinsic toe muscles stabilise the longitudinal arch and toes (Mann, 1979). Therefore, weakness of the toe flexor muscles will reduce the capacity of the toes to perform their normal function and potentially interfere with walking ability and balance.

Both qualitative and quantitative methods for determining toe flexor weakness have been found to be associated with not only poor performance in balance and functional tests in elderly people (Menz, 2005), but also an increased risk of falling (Mickle, 2009). However, these measures of toe flexor strength involve both the intrinsic and extrinsic toe flexor muscles and the relative contributions has not been determined.

In general, architecture of skeletal muscle is related to muscle function. For example, ankle dorsiflexion and plantarflexion strength has been found to significantly correlate with volume and cross-sectional area (CSA) of the corresponding muscle groups ( $r^2 > 0.46$ ; Gadeberg, 1999). However, very little is known about the relationship between the strength of the toe flexor muscles and their size. Therefore, the purpose of this study was to determine whether toe flexor strength is associated with muscle size of the toe flexor muscles.

### METHODS

The abductor hallucis, flexor hallucis brevis, flexor digitorum brevis and quadratus plantae muscles in the foot and the flexor digitorum longus and flexor hallucis longus muscles in the shank were assessed in 19 males and 21 females (mean age =  $28.9 \pm 8.1$  years; mass =  $75.2 \pm 15.0$  kg). Muscles were imaged using a GE Venue 40 US with a 6-9 MHz transducer.

Toe flexor strength was then assessed while each subject stood on an emed X pressure platform (Novel<sub>gmbh</sub>). During each trial subjects were instructed to push down as hard as possible onto the platform under two conditions: a) using their lesser toes, or b) using only their hallux. Maximum force (N) under the hallux and lesser toes were calculated and also normalised to body mass (% BW). Pearson Product Moment correlation coefficients were calculated to determine the strength of the relationships between toe flexor strength and muscle size.

### RESULTS

The maximum force produced by the hallux was significantly correlated with the thickness of the flexor hallucis brevis muscle ( $r = 0.46$ ,  $p < 0.01$ ). There was no significant correlation between the strength of the hallux and muscle size of abductor hallucis or flexor hallucis longus.

The maximum force produced by the lesser toes was significantly correlated with quadratus plantae CSA ( $r = 0.4$ ,  $p < 0.05$ ). There was no significant correlation between the strength of the lesser toes and muscle size of flexor digitorum brevis or flexor digitorum longus.

### CONCLUSION

Although this study was only conducted on a small sample, the results suggest that there is a correlation between size and strength of the toe flexor muscles. Interestingly, the strongest correlations were with the intrinsic foot muscles rather than the long flexor muscles. This may indicate that the static 'pushing down of the toes' action performed in the toe strength assessment is more closely related to the function of the intrinsic foot muscles. Further research is required to determine whether strengthening the toe flexor muscles results in hypertrophic changes to muscle morphology.

### REFERENCES

- Gadeberg *et al*, J App Phys 86:1670-1675, 1999.  
 Mann *et al*, Clin Orthop Res 142:24-29, 1979.  
 Menz *et al*, J Gerontol 60A:1546-1552, 2005.  
 Mickle *et al*, Clin Biomech 24:787-791, 2009.



## Fracture Analysis of Vertebra with Finite Element Method and Compare it with Experimental Data

Sara. Behforootan (1), Mehran. Kasra (2)

1. Master Student, School of Biomedical Engineering, Amirkabir University, Tehran, Iran
2. Associated professor, School of Biomedical Engineering, Amirkabir University, Tehran, Iran

### INTRODUCTION

Osteoporosis is a disease which characterized by loss bone mass and micro architectural deterioration of bone fragility and susceptibility to fracture [1]. Researchers have reported significant variation in tissue properties between normal and osteoporotic population [2]. Yield stress behavior of trabecular bone was presented by Keaveney and Kopperdahl in 1988 [3]. A vertebra may be divided into three parts; the first part is vertebral body constituting of trabecular bone block enclosed in a cortex formed by the cortical shell, laterally, and by the bony endplates, upwards and downwards. Schmidt et al, who also acquired on accurate CT scan-based geometry of a L4-L5 human lumbar spine segment, used a different approach to investigate the material properties of their particular model [4]. They iteratively calibrated the material properties of different modeled tissues by progressively incorporating these tissues in to the whole model and comparing the predictions with in-vitro experiments performed on geometrically reduced specimens. In this paper was decided to analyze fracture mechanism of vertebra with experiment and Finite Element on accurate geometry which has not done before.

### Materials and methods

#### 1. EXPERIMENT

Experimental test was taken place on T3 vertebra with its two lateral discs. This vertebra was taken from a cadaveric body which had osteoporosis. A compressive static load was applied on this vertebra. To achieve a more realistic model for FE analysis, CT scans of experimental sample were provided.

Low jaw apparatus was fully fixed and the upper jaw just moves in z direction. As you know the lower disc was fixed to lower jaw and the upper disc was so.

Fig 1 shows the experimental conditions.



Fig 1 Experimental conditions

#### 2. Finite Element model

The experimental conditions exactly were modeled in finite element in accurate geometry and analyzed.

### RESULTS

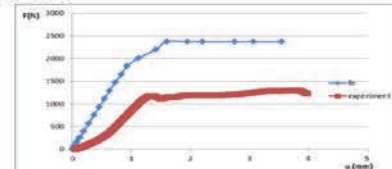


Fig 2 F-u diagrams. Lower: experimental data. upper:FE data

### DISCUSSION

Differences between the two diagrams from experimental and numerical solution are the most important topic. One of the first and important explanation comes to mind for these differences, is the material has been used in the simulation. General density was used for material selection and bone's porosity was relinquished. In fact bone is a non-homogeneous material and osteoporosis increases this non-homogeneity.

### References

1. Consensus development conference. American Journal of Medicine. 1993.
2. Homminga J MB, Ciarelli TE, Weinans H, Goldstein SA, Huiskes R. Cancellous bone mechanical properties from normal and patients with hip fractures differ on the structure level, not on the bone hard tissue level. Bone. 2002; 30(5): 759-64.
3. Kopperdahl D, Keaveny T. Yield strain behavior of trabecular bone. Journal of Biomechanics. 1998; 31: 601-608.
4. Schmidt,H., Heuer,F., Simon,U., Rohlmann,A., Claes,L., and Wilke,H.-J. Application of a new calibration method for a three-dimensional finite element model of a human lumbar annulus fibrosus. Clinical biomechanics. 2006; 21, 337-344.

## THE EFFECT OF WEIGHT-BEARING EXERCISE AND CALCIUM SUPPLEMENTATION ON THE TIBIA GEOMETRY AND MECHANICAL STRENGTH

Valiollah Dabidi-Roshan (1), Mahdi Hosseinzadeh (2), Mansour Eslami (1)

1. College of Physical Education and Sport Sciences, University of Mazandaran, Babolsar, Iran
2. Center for Sensory-Motor Interaction, Aalborg University, Aalborg, Denmark

### BACKGROUND AND OBJECTIVE:

Menopause is a risk factor for mechanical strength that changes the bone geometry properties. Calcium supplementation and weight-bearing exercise are known to affect skeletal development, but the single and combined effects of calcium and weight-bearing exercise on mechanical strength and geometry (histomorphometry) of weight-bearing bone are not well known, particularly during menopause. The objective of this study was to determine the effects of weight-bearing exercise and calcium supplementation on mechanical strength and geometry of tibia bone in ovariectomized rats.

Table 1: changes in trabecular mechanical strength and geometry properties outcomes in different groups.

	Endurance training		Ca supplementation		Training & supplementation		Sham-operate	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Weight (gr)	249±2	305±8 # * †	246±5	292±6 # * †	248±3	318±5 # *	248±6	279±7 *
Trabecular strength (N)	5.5±.8	7.2±1.4 # *	5.5±.8	7.1±1.5 # *	5.5±.8	7.2±1.2 # *	5.5±.8	5.4±.9
Cortical thickness (μ)	32.5±3	43.3±6.8 # *	32.5±3	36.4±9.6 # †	32.5±3	47.6±7.2 # *	32.5±3	31.5±4.8
Cortical volume (%)	20.8±.5	30.8±6.5 # *	20.8±.5	28.7±2.3 # *	20.8±5.8	31.6±2.5 # *	20.8±.5	21.5±4.6
trabecular thickness (μ)	7.6±1.3	11.6±3.6 # * †	7.6±1.3	9.8±1.6 # †	7.6±1.3	17.5±5.8 # *	7.6±1.3	5.1±1.2 *
trabecular volume (%)	72.1±.5	79.7±.5 # *	72.1±.5	76.3±2.5 # †	72.1±5.8	83.2±2.3 # *	72.1±.5	70.5±3.9
trabecular separation (μ)	17.8±.3	30.8±8.6 # *	17.8±.3	23.7±4.6 # †	17.8±3.7	34.1±3.8 # *	17.8±.3	11.8±1.5 *

\*significant difference comparing with pretest, # significant difference comparing with sham-operate group, † significant difference comparing with Training & supplementation (combined) group

### METHODS AND MATERIAL:

Fifty Sprague Dawley female rats were randomly divided into treatment groups (weight-bearing exercise, calcium supplement, and weight-bearing exercise +calcium supplement group), and sham-operate (control) group. The rats in the weight-bearing exercise groups performed a progressive endurance running training program consisting of 15 to 22 m/min for 25 to 64 min, 5 times a week for 8 weeks. Also, Calcium groups received Calcium supplement known as Osteocare Liquid (35 mg/kg in 5 days per week for 8 weeks) using Gavage. After 8 weeks, tibia bone mechanical strength was measured by HOUNSFIELD

system. Also, geometry (histomorphometry) parameters (volume and thickness in both the cortical and trabecular tissue and the trabecular separation) in the proximal tibia epiphysis were measured using a semi-automated image analysis system. Data was analyzed by one-way analysis of variance. Statistical significance was accepted at  $P<0.05$ .

### RESULTS:

The ovariectomy decreased the mechanical strength of tibia, the cortical and trabecular volume and thickness, and the trabecular separation in the proximal tibia epiphysis. Both of the weight-bearing exercise and calcium supplementation significantly increased cortical and trabecular volume and thickness, and the trabecular separation, as compared to age-matched control groups. The combined exercise + calcium group showed significantly larger positive effect in all the outcomes compared to exercise or calcium alone groups. Finally, the decrease in the bone mechanical strength followed by ovariectomy was significantly compensated only in the exercise +calcium supplementation group.

### CONCLUSION:

The result approved life style as an important determinant in prevention of osteoporosis. Both the weight-bearing exercise and calcium supplementation could induce an inhibitory and reversal effect on menopause-induced decrease in the mechanical strength and histomorphometric outcomes of weight-bearing bones. The combination of exercise training and calcium supplementation has a far better effect on the geometry and mechanical strength of weight-bearing bones rather than using each of them separately.

### References

1. Marinozzi F, Marinozzi A, Bini F, Zuppante F, Pecci R, Bedini R. Variability of morphometric parameters of human trabecular tissue from coxo-arthritis and osteoporotic samples. *Ann Ist Super Sanita*. 2012;48(1):19-25.
2. Krystyna siężopolska - Orłowska. Changes in bone mechanical strength in response to physical therapy, *POLSKIE ARCHIWUM MEDYCYN WĘNĘTRZNEJ* 2010; 120 (9); 368-373.
3. S. Tournis, E. Michopoulou, I. G. Fatouros, I. Paspatis, M. Michalopoulou, P. Raptou, Effect of Rhythmic Gymnastics on Volumetric Bone Mineral Density and Bone Geometry in Premenarcheal Female Athletes and Controls. *J Clin Endocrinol Metab*, 2010; 95: 2755–2762.

## APPLY TIME SERIES MODELING IN GAIT KINEMATIC ANALYSIS DURING SLIPS

Xinyao Hu (1), Xingda Qu (1)

1. Center for Human Factors and Ergonomics, Nanyang Technological University, Singapore

### INTRODUCTION

Slips are one of the most commonly happened hazards during walking (Courtney, 2001). A complete understanding of joint pressure, force and moment distribution is important in slip related studies. Practically, to obtain joint kinetic distribution profiles, the commonly used approach is through inverse dynamics which combines ground reaction forces and kinematic measures from corresponding body segments. Therefore kinematic measures are essential in the sense of obtaining a comprehensive insight of joint kinetics. Most analytical methods for kinematic measures were based on parameterized approach, namely, critical measurements such as peak amplitude were abstracted and analyzed. However, there might be potentially valuable temporal patterns discarded (Chau 2001). This study introduces a novel method of seasonal autoregressive integral moving-average (SARIMA) model based time series analysis to develop individual specific model for gait kinematic measures during slip during walking.

### METHODS

The experimental design and data acquisition were introduced elsewhere (Hu, 2011). Ankle joint accelerations for four participants were analyzed in this study because ankle acceleration was commonly used in inverse dynamics approach for calculating lower limbs joint pressure and force. The calculation of ankle acceleration followed the ISB recommendation (Wu, 2005). The development of SARIMA model followed the method suggested by Montgomery (1990).

### RESULTS

The general SARIMA model selected based on method suggested by Montgomery (1990) can be written as:

$$\begin{aligned} & \Phi_p(B^s)\phi_p(1-B)d(1-B^s)Z_t \\ & = \theta_q(B)\Theta_Q(B^s)a_t \end{aligned} \quad (1)$$

Where  $Z_t$  represents original kinematic measure and  $a_t$  represents time series residual.  $\Phi_p$  and  $\phi_p$  are

seasonal and regular autoregressive parameters,  $\theta_Q$  and  $\theta_q$  are seasonal and regular moving-average parameters.  $B$  is the back-shift operator,  $S$  and  $d$  represents level of seasonal and regular differencing level respectively.

Table 2 shows SARIMA model parameters for ankle joint acceleration during slips. The specific parameters characterize each kinematic measure from different slip trials, the corresponding SARIMA model is able to generate identical and independently distributed time series.

	S	d	$\Phi_p$	$\phi_p$	$\theta_q$	$\Theta_Q$
P1	51	1	0.32	0.13	0.16	0.13
P2	50	1	0.11	0.42	0	0.35
P3	49	1	0.14	0.34	0.32	0.13
P4	53	1	0	0.27	0.17	0.16

Table 2: SARIMA model parameters for ankle joint acceleration measures during slip.

### DISCUSSION

Kinetic measures become meaningful in gait analysis only when it is combined with kinematic data (Whittle, 2007). The combination provides much more complete mechanical description of gait than either by itself. This study introduced a novel analytical method for kinematic measures based on time series SARIMA models. This method can eventually generate time series residual that preserve the temporal properties of original data and identical and independently distributed. The future application of this study includes applying conventional statistical analysis or advanced statistical process control method on the time series residual generated from this modeling. The authors believe this method can also be applied in pressure distribution data from joints.

### REFERENCES

- Chau, Gait&Posture 13:102-120, 2001.  
 Courtney *et al*, Ergonomics 44(13):1118-1137, 2001.  
 Hu *et al*, Ergonomics, under revision, 2011.  
 Montgomery *et al*, Forecasting and Time series Analysis, 1990.  
 Whittle, Gait analysis: An introduction, 2007.



## PLANTAR PRESSURE DISTRIBUTION OF DIFFERENT FOOT MODELS DURING CUTTING MOVEMENTS

Stefan Lehner, Christine Dießl, Dennis Chang, Veit Senner

Technische Universität München, Institute of Ergonomics, Department Sport Equipment and Material, Boltzmannstraße 15, 85747 Garching, Germany

### INTRODUCTION

Cutting movements induce high loads on the anterior cruciate ligament in the knee. The injury risk is affected by the shoe-surface interaction. For the evaluation of different influencing factors of this interaction the TrakTester, a custom-made device, was used (Grund 2011). To achieve significant results for the ACL loading a realistic plantar pressure distribution in the shoe is required.

### MATERIAL AND METHOD

With the TrakTester several cutting movements were carried out using two different foot models.



Figure 1: TrakTester (at the top) an, adjustable (bottom left) inflexible foot models (bottom right)

The plantar pressure distribution was analyzed with three different systems:

- The original foot model with Parotec insoles (24 integrated sensors; Paromed GmbH, Markt Neubeuern, Germany),
- the modified version of this foot model with Pedar-X insoles (99 sensors; novel GmbH, Munich, Germany) and
- the inflexible model was surveyed with the OpenGo science system (13 sensors, Moticon, Munich, Germany).

For the inflexible model distinct angles between the lower leg and the surface were adjusted and the obtained plantar pressure distributions were analyzed.

### RESULTS AND DISCUSSION

Fig. 3 shows the plantar pressure distributions of the different foot models. As the first version showed high pressures in the arch region, it was modified to

reduce the load in this area. A second inflexible model induced the pressure in the heel and forefoot region.

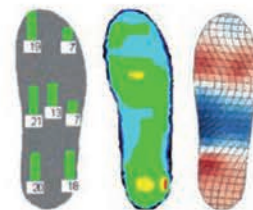


Figure 2: Pressure distribution at the initial foot model (Parotec, left, Grund 2011), the modified model (Pedar-X, middle) and the inflexible model (OpenGo, right)

For various angles similar plantar pressure distributions were obtained. Highest pressures were applied on the medial side of the heel and forefoot with minor load in the arch region. This corresponds to literature data investigating cutting movements with subjects (Eils 2004, Orendurff 2008, Wong 2007)

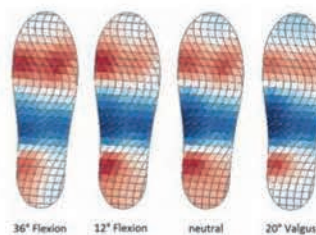


Figure 3: Similar results of the inflexible model testing different angles between the lower leg and the surface

### CONCLUSION

Tests with the inflexible foot model achieved similar and realistic patterns of the plantar pressure distribution for different angles. This is an important precondition to obtain reproducible data for ACL loading during cutting movements.

### REFERENCES

- Eils et al, Am J Sports Med 32(1), 140-145, 2004.  
 Grund, Dissertation, Universität Koblenz, 2011.  
 Orendurff et al, Am J Sports Med 36(3), 566-71, 2008.  
 Wong et al, Br J Sports Med 41(2), 93-100, 2007.

## COMPARISON OF GAIT STAGES IN WOMEN OF DIFFERENT AGE.

Martin.Sebera, Radek. Musil, Jan. Šenkýř, Josef. Michalek

Department of Kinesiology, Faculty of Sports Studies, Masaryk University, Czech Republic

### INTRODUCTION

Walking is characteristic for each human. People learn it, create a personal pattern during the period of adolescence and maintain it during adulthood. Mainly dynamic characteristics of gait are maintained for a relatively long period; changes appear as a consequence of decreasing quality of force abilities.

The pilot study researches the duration of a single and double limb stance of natural gait in women of middle and elderly age, i.e. when such dynamic characteristics can become a subject to change.

### METHODS

Subjects: 60 women with ordinary physical activities participated in the study. They were divided into three groups according to their age (A 30 – 39, B 40 – 49, C over 50). Each group contained 20 women. The average age in the first group was 33.9 ( $\pm 2.6$ ), in the second 42.6 ( $\pm 3.0$ ) and in the third one 57.0 ( $\pm 6.4$ ). Instrumentation: questionnaire, capacitive pressure insoles in the shoe (Pedar Mobile, Novel Munich, 99 sensors, 50 Hz). Protocol: laboratory survey, each woman performed three attempts of natural walking in the length of 15 m, two of them were for training, the final attempt was monitored. Three stances of each leg were assessed, always from between the third and eighth steps. Parameters: time of stride, stance and swing. Statistics: ANOVA descriptive statistics.

### RESULTS

When analyzing the results of time data for individual gait stages between the right and left legs, no significant differences have been found. Statistically significant differences have been found in individual stages between age groups.

Group	Stride [s]	Stance [s]	Swing [s]
A	1.08	0.66	0.42
B	1.12	0.69	0.44
C	1.11	0.69	0.43

Tab. 1 Overview of duration of individual gait stages.

As the results suggest, stride prolongs with growing age: it was prolonged by 3.7 % between groups A and B, and by 2.8 % between groups A and C. Such differences were not statistically significant. Stride prolonging occurred by prolonging both stance and

swing stages evenly. The longest proportional share of stance has been found in the eldest group C and the differences between this group and groups A and B were statistically significant ( $p=0.002$ ,  $p=0.000$  resp.).

Group	Stance [%]	Swing [%]
A	60.92	39.16
B	60.80	39.35
C	61.77	38.13

Tab. 2 Overview of percentage representation of stance and swing in stride.

Logically enough, the shortest swing has been found in group C, the difference between C and A and B was, again, statistically significant ( $p=0.001$ ,  $p=0.000$  resp.).

Group	LR [%]	MSt + TSt [%]	PS [%]
A	10.96	39.21	11.26
B	10.77	39.36	10.64
C	11.75	38.89	11.82

Tab. 3) Percentage representation of single and double limb stance stages.

From stance analysis, it follows that single limb stance (MSt + TSt) does not change much with growing age (there is only a minor decrease), more dramatic changes, however, appear in double limb stance during Loading Response and Preswing. The longest Loading Response has been found in the eldest group C, if compared with group A, it was longer by 0.79 % in average; if compared to group B, it was longer by 0.98 %. These differences were statistically significant ( $p=0.004$ ,  $p=0.000$  respectively). The time of Preswing was significantly different only between groups B and C, by 1.18 % ( $p=0.013$ ).

### CONCLUSION

In the observed groups of women, a tendency has been found to prolong stance duration, which was caused by prolonging double limb stance. It is a logical consequence of the need of better stability in the gait of elderly people.

### REFERENCES

- Ayyappa J.Prost. Orth. 9, 1, p 10, 1997.
- Nykodým *et.al.* Tel.kult.30:2,59-71, 2007.
- Zvonař *et.al.* Brno, Masarykova univerzita, 2010.

# CAN ORTHOSES AND NAVICULAR DROP AFFECT FOOT MOTION PATTERN DURING RUNNING

Mansour Eslami (1), Valiollah Dabidi-Roshan (1)

1. Faculty of Physical Education and Sport Sciences, University of Mazandaran, Babolsar, Iran

## BACKGROUND AND OBJECTIVE:

It is unknown whether or not forefoot-rearfoot coupling patterns are different between individuals with different navicular drop measures during orthoses and no orthoses conditions. The purpose of this study was to examine the effect of a semi-rigid foot orthotic device on variations in forefoot-rearfoot joint coupling patterns in individuals with different navicular drop measures during the stance phase of running. We hypothesized that forefoot-rearfoot coupling patterns would be different between individuals with different navicular drop measures during orthoses and no orthoses conditions.

## METHODS AND MATERIAL:

Twenty-three able-bodied male students having no regular physical activity and an average age of 27.2 (SD 5.1 years), mass of 84.4 (SD 9.2 kg) and height of 179.0 (SD 5.9 cm) volunteered. Six cameras (Motion Analysis Corporation, Santa Rosa, USA) were arranged along two arcs on the left and right sides of a force plate (960 Hz, AMTI, Model OR6-5) placed in the middle of a 10 m runway. Ten running trials were performed in a block random order while subjects ran shod under two conditions: 1) with orthoses and 2) without orthoses. In each experimental condition, the subject ran at a controlled cadence of 170 steps per minute (2.23 m/s). Navicular drop (ND) for each subject were determined using the method proposed by Loudon et al.<sup>1</sup> In order to determine foot motion pattern, an angle-angle diagram was constructed from the relative excursions between successive sampled data points of forefoot and rearfoot angle during 4 period of stance phase. Then the angle of these points, with reference to the horizontal axis, was computed as described by Freeman<sup>2</sup> as:

$$F_i = \arctan \left[ \frac{(\theta_{yi+1} - \theta_{yi})}{(\theta_{xi+1} - \theta_{xi})} \right]$$

Where,  $\theta_y$  and  $\theta_x$  represented the forefoot and rearfoot frontal plane rotation. A three-way ANOVA was performed by setting two dependent factors as four phases (phase1× phase2×phase3×phase4) as well as two conditions (orthoses × no orthoses) and an independent factor as navicular drop (low × high).

## RESULTS:

Eleven subjects were classified as ND 2< and ≤5 mm and 12 subjects were classified as ND ≥ 7 mm. Despite inter-subject differences in coupling angles over four phases, the results of the present study show that mean coupling angles increased from phase1 to phase 4 in the no orthoses condition whereas it only increased from phase 1 to phase 3 during the orthoses condition within groups. Statistical analysis showed that there were no interaction effects among three factors of coupling angle, condition, and navicular drop (p=0.16). However, an interaction effect of condition and phase was observed (p=0.01; effect size= 0.72). This finding provides evidence that the coupling angle differed across orthoses conditions over all four phases. Specifically, forefoot-rearfoot coupling motion in the no orthoses condition increased at a rate faster compared to the orthoses condition from phase 1 to phase 4. Running with orthoses reduced this rate by decreasing coupling angle at phase 3 and 4 of stance which accounts for 46% of the variance in coupling angles during running (p=0.02).

## CONCLUSION:

A custom made semirigid foot orthoses could significantly decrease the frontal plane forefoot-rearfoot coupling angle after heel strike phase and during midstance. However, differences in navicular drop measures were not an influencing factor in changing this coupling pattern of these two segments.

## References

1. Loudon JK, Jenkins W, Loudon KL. The relationship between static posture and ACL injury in female athletes. *J Orthop Sports Phys Ther* 1996; 24:91-7.
2. Freeman H. A technique for the classification and recognition of geometric patterns. In *Proceedings of the 3rd International Congress on Cybernetics*. Namur: Belgium; 1961



# ON THE EFFECTIVENESS OF THE NEWLY DEvised ERGONOMIC CHAIR WITH CHEST SUPPORT BY EVALUATION OF MUSCLE ACTIVITY AND CONTACT LOAD

Jong Hyun Kim, Seung Yeop Lim, Jae Soo Hong, Keyoung Jin Chun, #Byeong Hee Won

Gerontechnology Center, Korea Institute of Industrial Technology, Korea  
#Corresponding and Presenting Author: bhwon@kitech.re.kr

## INTRODUCTION

This study is aimed at evaluating the effectiveness of an ergonomic chair with chest support, which is designed for supporting the forearms and torso. Conventional office chairs usually impose a physical burden on the vertebra. Muscle activation and contact load were analyzed for four different seating postures (M. Graf, 1994; Gordon A. Vos, 2006; Rolf P. Ellegast, 2012).

## METHODS

**Subjects:** After approval from the Institutional Review Board, five healthy males ( $29.6 \pm 1.95$  years,  $175.4 \pm 4.67$ cm, and  $72.8 \pm 4.19$ kg; mean  $\pm$  SD) were selected for participation in the study.

**Seating postures in ergonomic chair with chest support:** In posture1 ( $P_1$ ), the chest and the forearms are supported on the ergonomic chair with chest support. However, in posture2 ( $P_2$ ), the forearms are supported but the chest is not. In posture3 ( $P_3$ ), the chest is supported but the forearms are not. Posture 4 ( $P_4$ ) involves an upright sitting position ( $90^\circ$  flexion of the hip joint).



Figure 1: 4 Seating postures ( $P_1$ ,  $P_2$ ,  $P_3$ ,  $P_4$ )

**Measurements and data acquisition:** We selected three different muscles, namely, the upper trapezius (U.T.), lower trapezius (L.T.), and the erector spine (E.S.) in order to analyze muscle activation (Rolf P. Ellegast, 2012). The muscles could be measured by surface electromyography (sEMG). The measurements were made using a six-channel wireless sEMG (Delsys Inc., USA).

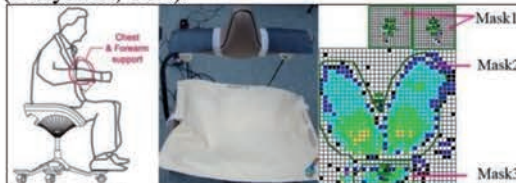


Figure 2: Ergonomic chair with chest support (left), pressure measuring system (center), masking contact area (right)

The pressure distribution and force at the contact area were measured using a pressure mapping system

(Pliance FTX, Novel, Germany) to determine contact load characteristics.

**Data analysis:** EMG data were post-processed, which involved filtering (FIR, band-pass: 20–350Hz), rectification, and smoothing (RMS: root mean square, sampling: 50ms). On the basis of  $P_4$  muscle activation, the collected EMG data were normalized using reference voluntary contraction. According to Figure 1 (right), contact load characteristics were divided into three areas: Mask1 ( $M_1$ : forearms), Mask2 ( $M_2$ : hip, thigh), and Mask3 ( $M_3$ : posterior pelvic). Further, the mean pressure (MP) and force (F) were analyzed.

## RESULTS AND DISCUSSION

	$P_1$	$P_2$	$P_3$
U.T.	148.1( $\pm 7.2$ )	138.2( $\pm 3.6$ )	277.0( $\pm 116.6$ )
L.T.	167.6( $\pm 11$ )	151.2( $\pm 13.7$ )	202.5( $\pm 24.6$ )
E.S.	97.3( $\pm 14.2$ )	89.5( $\pm 16.3$ )	184.6( $\pm 39.0$ )

Table 1: Results of Muscle Activity ( $p < 0.05$ ), (Unit: %RVC)

		$P_1$	$P_2$	$P_3$	$P_4$
$M_1$	MP	99.6 ( $\pm 33.6$ )	88.1 ( $\pm 32.1$ )	-	-
	F	47.6 ( $\pm 8.0$ )	44.1 ( $\pm 17.9$ )	-	-
$M_2$	MP	107.0 ( $\pm 7.2$ )	106.2 ( $\pm 10.7$ )	124.3 ( $\pm 6.9$ )	135.7 ( $\pm 7.8$ )
	F	1218.0 ( $\pm 235.3$ )	1303.0 ( $\pm 163.4$ )	1550.0 ( $\pm 172.6$ )	1704.0 ( $\pm 161.4$ )
$M_3$	MP	89.2 ( $\pm 11.1$ )	84.8 ( $\pm 12.8$ )	81.8 ( $\pm 27.7$ )	51.8 ( $\pm 20.1$ )
	F	137.6 ( $\pm 60.0$ )	123.8 ( $\pm 48.4$ )	119.2 ( $\pm 84.0$ )	36.6 ( $\pm 34.8$ )

Table 2: Results of Contact Load ( $p < 0.05$ ), (Unit: MP [mmHg], Force [N])

**Discussion:** Forearm supported posture  $P_2$  showed the lowest muscle activation characteristics in the E.S. that is used to help back extension. Analysis of contact load characteristics showed that the forearm support ( $P_1$  and  $P_2$ ) enabled reduced contact load in  $M_2$  compared with the normal sitting postures  $P_4$ . This study confirmed that the newly devised ergonomic chair function reduced muscle stress on the spinalis and the contact load on the thigh and hip (or the bottom).

## REFERENCES

- M. Graf *et al.*, J Industrial Ergonomics 15:81-89, 1995.
- Gordon A. Vos *et al.*, Appl. Ergo. 37:619-628, 2006.
- Rolf P. Ellegast *et al.*, App. Ergo. 43:296-307, 2012.



## THE INFLUENCE OF HEEL HEIGHT AND OF CONSTRUCTION OF THE HEEL ON PLANTAR PRESSURE

Barbora Foltynova, Martina Cernekova, Petr Hlavacek

Department of Physics and Material Engineering, Faculty of Technology, Tomas Bata University in Zlin, Czech Republic

### INTRODUCTION

Contemporary footwear is a fashion accessory designed to satisfy customers. Health aspect is postponed to the background, and therefore on the market there are shoes that may endanger the foot. One of such displays is heel height, which changes the center of gravity and can even hurt the human foot. Due to this, illnesses like foot splayed, vertical feet, hammer toes, bunions and shortened calf muscles, can occur. However, optimal heel height may have a beneficial effect on the foot, because it makes walking easier and reduces impacts when walking. On the other hand, high heel shifts the load of the foot to the front, where it leads to its congestion. The aim of this research was to determine the extent to which heel height affects walking in different terrains. [1]

### EXPERIMENTAL

Walking in a variety of terrain was simulated by the inclined plane which was constructed for this measurement. This inclined plane imitated walking down the hill. Measurements were performed on the instrument PEDAR® (Novel GmbH, Munich). For this research shoes that had a different heel height were selected. It was a women's footwear in size 37. Five pairs of shoes with different height heels and sixth pair of flat shoes with soft soles were chosen for this research from company Gabor. The heels differed in shape and location of the heel, but just subtly. We measured fifteen women from the ranks of students and university employees who fitted the chosen shoes (had foot size 37). In course of measuring the plantogram from which direct foot length was investigated was created. This was employed to calculate the size number, and the finger jointlines had been investigated while loading and reducing the load on the finger joints. Age of women who took part in this research was  $24 \pm 4$  years, body height  $1.59 \pm 0.03$  m and body weight  $52.4 \pm 5.6$  kg.

### CONCLUSIONS

A mask for all measurements was created in the Novel Database for M 12.2.9. This mask divides the area of measured foot into two parts - the heel area (MO1) and the tiptoe area of foot (MO2). Graphs for each level of tilt were constructed. In these graphs the graphical relationship between heel height and the difference pressure for the heel and toe is displayed (Figure 1).

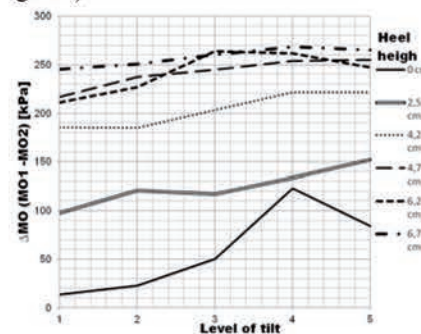


Figure 1: Graphical dependence of level of tilt on the difference pressure

The graph shows that with increasing heel height maximum force in the front increases and vice versa in the heel part force decreases. Maximum power of walking on low heels is around 250 kPa. With the gradual increase in the heel the power increases up to 400 kPa. Also the influence of an inclined plane was manifested - the higher the level of tilt, the greater the load of fingers. Therefore it is likely that walking in uneven terrain can significantly increase the maximum pressure acting on the front foot. [2,3]

### REFERENCES

- [1] Grim M., Druga R. (2001)
- [2] Cavanagh P.R. et al. (1994)
- [3] Rosenbaum D. et al. (1994)



## EFFECTIVE COMBINATION OF NEW BONE SUBSTITUTE AND SCREWS IN THE JAIL TECHNIQUE: A BIOMECHANICAL STUDY OF TIBIAL DEPRESSION FRACTURES

**Stefanie Doht, Teresa Lehnert, Sönke Frey, Kai Fehske, Hendrik Jansen, Torsten Blunk  
Rainer H. Meffert**

Department of Trauma, Hand, Plastic and Reconstructive Surgery  
University Clinics of Wuerzburg, Germany

### INTRODUCTION

Tibial plateau depression fractures (Type AO-B2, Schatzker III) are frequently seen after low velocity injuries in the elderly (Kösters, 2011). Depression of the articular surface requires fragment elevation and safe retention. Compression defects of cancellous bone after articular reconstruction may lead to secondary loss of the reduction (Wirth, 2010). Biomechanical investigations of the operative treatment are rare and only determined crest bone graft versus bone substitute (Yetkinler, 2001; Welch, 2003). The aim of this study was to investigate the importance of both components, new bone substitute, drillable calcium phosphate cement (Norian drillable), and screws in the jail technique with regard to the primary stability in lateral tibial depression fractures.

### METHODS:

Lateral tibial depression fractures were created in a biomechanical fracture model using osteoporotic human tibiae (Karunakar, 2002). After reduction they were stabilized with bone substitute (group 1), bone substitute with additional four screws in the jail technique (group 2) or four screws only (group 3). After fixation the biomechanical tests with cyclic loading (20-250N, 3000 cycles) and load-to-failure tests were performed in the test machine Zwick/Roell 2020. Displacement, stiffness and maximum load were determined. Data was evaluated statistically by analysis of variance (ANOVA).

### RESULTS:

The 1st and 2nd group revealed a significantly lower displacement (Figure 1) and higher stiffness than group 3 without bone substitute (only fixed with screws). The maximum load was higher for the groups with screws (group 2 and 3) compared to the group with bone substitute (Norian Drillable) only (Figure 2).

### DISCUSSION

A metaphyseal defect remains after reduction of the articular fragment in tibial plateau depression fractures, in particular in the presence of osteoporosis (Kösters, 2011). New drillable calcium phosphate

cement as bone substitute reduced the displacement of the depression fracture fragment under conditions simulating a clinical relevant partial weight bearing, and screws in the jail technique increased the maximum load. Thus, in the operative treatment of tibial depression fractures, for the primary stability only a combination of bone substitute and screws provide enough stability.

### FIGURES

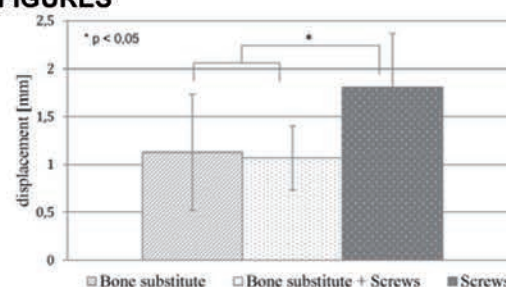


Figure 1: For the groups with bone substitute, the displacement was lower than for the group without bone substitute.

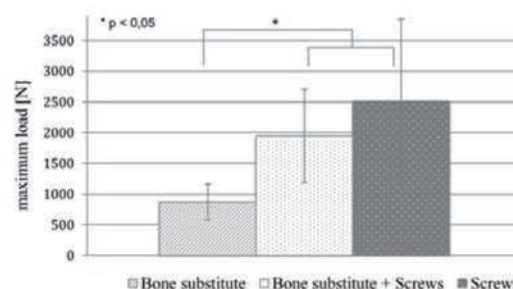


Figure 2: For the groups with screws, the maximum load was higher than for the group without screws.

### REFERENCES

- 1 Karunakar et al, JOrthopTrauma 16, 3;172-177
- 2 Kösters et al, Unfallchirurg 114, 3;251-260
- 3 Welch et al, JBJS Am, 85-A, 2; 222-231
- 4 Wirth et al, Complications in Orthopaedic Surgery
- 5 Yetkinler et al, JOrthopTrauma 15, 3;197-206



# BODY PRESSURE MEASURING DEVICE FOR THE PREVENTION AGAINST BEDSORES

Kyung-bae Jang , Kyeong-wan Lee, Do-hoon Koo

National Rehabilitation Center Research Institute, Seoul, Korea

## ABSTRACT

The disabled on the move using wheelchairs need to have cushions possible to distribute the force being applied to wide ranges to reduce the risk of bed sore. When sitting for a long time continuously without reducing the concentration of pressure, the bed sore will damage tissues of skin and can cause the serious infection which may threaten the life. When sitting in the upright posture, larger proportion of body weight is concentrated on the ischial tuberosity. Therefore, more fundamental prevention from bed sore must be accomplished by providing information on body pressure. Accordingly, it was designed so that it can be supplied to the more disabled through development of the body pressure measuring system which shows the body pressure distribution and the low-price development.

## 1. INTRODUCTION

The wheelchair prescribed by mistake can deteriorate problems in relation to the disability actually, and can cause various deformities of body segments such as scoliosis, kyphosis, especially bed sore. When sitting for a long time continuously without reducing the concentration of pressure, it can make the bed sore occurred due to the damaged tissues of skin. It is difficult to prevent bed sores fundamentally because of lack of information on the body. The bed sore is occurred frequently at the pelvis which is the protruding part of bone to the wheelchair riders. Thus, the fundamental prevention against bed sore must be accomplished by providing information on the body pressure.

## 2. METHOD

### 2.1 Body pressure measuring device

Although some of the devices for measuring the pressure distribution of sitting posture by using pressure sensors have been developed, it has the demerit for the individual difficult to carry with since its price is very high. To solve this problem, we developed our low-price highly precise movable measuring device by using sensor mats with FSR (Force Sensing Resistor) method, and it was designed so that it can provide continuous information on the body pressure distribution through mobile terminal (Fig. 1).

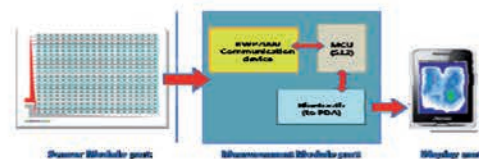


Figure 1: Concept diagram of body pressure measuring device

### 2.2 Thin-Film type FSR sensor

Developed sensor can be divided into the silver pattern at the upper end part and the carbon pattern which is the resistance. The physical properties for sensor apply the input power supply (VIN) to the blue shape part at the left side in Fig. 2 and measure the output power supply (VOUT) from the red shape part at the right side.

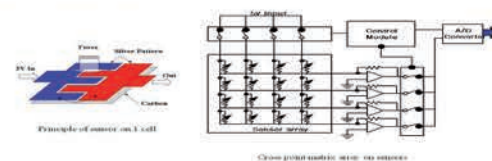


Figure 2: Principle of development and the electric circuit diagram of FSR body pressure measuring sensor

## 3.RESULT & DISCUSSION

We developed our low-price highly precise movable measuring device by using sensor mats with FSR (Force Sensing Resistor) method as a measurement plan for providing continuous information on the pressure distribution to the disabled and the old & feeble persons who conduct daily lives by using wheelchairs and that for effective prevention against their bed sores.

In the future, it is required to be designed so that the individual can carry it with him/her and the information on body pressure distribution can be provided through mobile terminal to provide continuous information on the pressure distribution.

## REFERENCES

- Bergstorm *et al.*, Nursing Research 36(4): 205-210, 1991.
- Davalos *et al.*, Clinical Nutrition, 10(5): 245-250, 1991.
- Nelham *et al.*, Journal of Biomedical Engineering 3(4): 267-274, 1981.

## COMPARISON OF THE CONTACT AREA OF SOLE AND SURFACE IN COMBAT SPORTS USING PEDAR

Jan. Šenkýř, Martin. Zvonař, Zdenko. Reguli

Faculty of Sports Studies, Masaryk University, Czech Republic

### INTRODUCTION

This work is a pilot research for a doctoral thesis named "Diagnostics of the Condition of Instep in Combative Disciplines" written by the first author of this text. It is an attempt to compare and express in numbers the values which are related to the contact of the foot with the surface in combative sports. Out of the measured values, we are mainly interested in the values concerning maximum contact with the surface during one step, the number of steps in a time period, comparing the size of the contact area of the front and rear parts of the foot etc. The values of mean pressure are rather an additional complement to the comparison with the values of the size of the contact area.

An important limit which affected the research was methodology of measuring bare feet of combative athletes which has not been elaborated so far. Therefore, the author also attempted to create such a methodology that could result in the possibility of using insoles with the Pedar device.

### AIM

The main aim of this work is to specify and compare the values of the contact area of the foot and the surface in four combative sports. Another, but not inferior, aim is an attempt to create methodology for using the Pedar device for measurements in combative sports.

### METHODOLOGY AND METHODS OF MEASUREMENT

Measuring was carried out in combative gym on a tatami mat. Pedar by Novel Company was chosen as a suitable device for getting required values. This pilot research comprised 4 groups of probands, namely judo and karate fighters, boxers and kick-boxers. Always, one proband was being measured who conducted a 60-second training fight against an opponent. The fight was specific in the fact that the measured proband could involve all techniques against the opponent without exceptions. On the other hand, the proband who was not being measured only pretended attacks and he played the part of a defense fighter. Three probands of each of the combat sports took part in measuring. The differences in weight of the probands were  $\pm 5$  kg and the size of foot of all of them was 45 (according to European standards).

The device was placed around the waist of the proband, on keikogi. The insoles used for measuring

when they are placed in the shoe were fastened to the soles of the feet wearing socks. They were fastened with a special, antiskid, elastic bandage. The whole foot with the insole has been dressed in a neoprene sock used in water sports.

### RESULTS OF THE MEASUREMENTS

As far as the results are concerned, we were mainly interested in the values related to the average number of steps during the whole fight (i.e. 60 s). From this point of view, Table 1 identifies boxing as the sport with the largest number of steps. At first sight, it could be said that this value is related to the value of the average contact area. However, this value was the lowest in boxing. The smallest number of steps was counted in karate.

	Weight	Foot	Steps	Area	Max Pressure	Mean pressure
	[kg]			[cm <sup>2</sup> ]	[kPa]	[kPa]
Judo	77.4	L	92	144	187.5	66.2
		R	93	135	274.1	63.5
Box	74.3	L	112	87	435.8	109.1
		R	129	95	352.5	107.1
Karate	78.1	L	78	154	175.8	65.3
		R	79	155	274.1	62.4
Kick-Boxing	76.5	L	91	136	211.6	66.1
		R	93	149	218.3	75.9

Tab. 1: Results of the pilot research

### CONCLUSIONS

The first attempt to create methodology for using the Pedar device for measurements in combat disciplines was successful; 12 people were measured. We will further try to eliminate specific difficulties related mainly to the issue of surface sliding. According to the subjective opinions of the probands, the device fastened to their body is also to a certain extent limiting. For our purpose of comparing mainly the contact area of the foot and the surface, the location and fastening of the device to the sole of the foot has proved sufficient. We were also enabled by this research to describe movement stereotypes in individual combative sports in focus.



## LATERALITY AND SKATING TECHNIQUE IN CROSS-COUNTRY SKIING

Soňa Jandová, Jan Charousek

Faculty of Science, Humanities and Education, Technical University of Liberec, Czech Republic

### INTRODUCTION

Laterality affects human motorics in both unilateral and bilateral movements. Right foot preference is manifested in approximately 80 % of the overall population (Porac *et al.*, 1981). The influence of lateral preference on the quality of sport and basic movements has been investigated in several papers (e.g. Vaverka, 2005). Based on the personal experience of cross country skiers, we can assume that most of them favor a stronger take off either from the right or from the left ski when skating. It can be expected that lateral preference with regard to the lower extremities can influence fluency of the run. We can also set up an alternative hypothesis and assume that there are no differences in the execution of a take off from the left and right foot in very experienced and long-term trained cross country skiers.

### METHOD

Five very skilled cross-country skiers (members of Czech Nordic Combined National team), four of them with the right foot preference during take off and two of them with left foot preference during take off, participated in this research. They performed eight runs with the length of 100 m. Four of them were on the flat track, two on the light hill and two on the steep uphill. Skiers should perform on the flat track double polling technique during 2 runs and one-polling technique during 2 runs. They had to perform double polling too when skating up the hill. For monitoring, a synchronized video recording was utilized together with the mobile pedographic system Pedar (Novel). For the detection of lateral preferences of lower limbs, common diagnostic methods used in kinanthropology were applied. An Analysis of the final reaction force  $F_z(t)$  provided us with information about the duration of each take off, the magnitude of the maximal force produced in take off achieved on the right and left foot. We also computed indices of symmetry ( $IS = R/L$  leg) from the obtained data, and then performed a statistical analysis on all variables.

### RESULTS AND DISCUSSION

The results of the statistical analysis showed significant differences between take off from the dominant and non-dominant leg in all observed

variables. Two of three skiers whose right foot is preferred for take off achieved higher values of the maximal force on their dominant – right leg. Both skiers who preferred left leg in take off achieved higher values on their left - dominant leg (from the point of view of the leg which is taking off). One of the skiers who preferred right leg for taking off achieved similar values on both legs (604 versus 579 N).

From the point of view of practice we can ascertain that take off of the dominant leg is executed by higher force and faster (during shorter time) than by the opposite leg. The observed findings are surprising with regard to the fact that the subjects of the research were very skilled cross-country skiers (two top world racers among the set) with lifelong top-level skiing experience.

### CONCLUSION

The lateral preference was manifested in symmetrical double polling skating technique by a shorter duration of the take off and higher forces produced on the preferred leg (from the point of view of the leg which is taking off). The dynamometry of the cross-country skating technique seems to be an appropriate method for an assessment of the quality of a take off execution.

### REFERENCES

- Porac, C. *et al.*. Lateral Preferences and Human Behavior. New York: Springer-Verlag., 1981.
- Vaverka, F. Laterality and effectivity of human movement – the biomechanical point of view. Science and Profession – Challenge for the Future“, 808-814, 2005.



## ANALYSIS OF GAIT BALANCE CHARACTERISTICS IN OLD HEMIPLEGIA PATIENTS FOR DEVELOPMENT OF REHABILITATION TRAINING SYSTEM

Hyunho Choi (1), Bumkee Lee (2), Dohyung Lim (2), Juwon Ko (2), Leeyong Song (2)  
#Keyoungjin Chun (1)

1. Gerontechnology research group, Korea Institute of Industrial Technology, South Korea
  2. Dept. Mechanical engineering, Sejong University, South Korea
- # Corresponding and Presenting Author: chun@kitech.re.kr

### INTRODUCTION

This study aimed at 1) identification of the gait characteristics of hemiplegia patients by comparing with those of normal healthy young and old people (Kelley, 2009) and 2) suggestion of muscle actuator control strategy for gait balance recovery through gait balance rehabilitation training system with mobile function.

### MATERIALS AND METHODS

**Participants:** Following Institutional Review Board approval, six hemiplegia patients ( $64 \pm 15$  years) with left hemiplegia, six healthy male ( $26 \pm 4$  years) and six elderly male ( $71 \pm 6$  years) were participated.

**Upright Postural Stability:** The balance system SD (BIODEX, USA) was used to identify a degree of postural stability under a static condition. The postural stability were then judged through placing a marker in center of the screen grid of the balance system SD. Here, the postural stability tests were performed for 10 seconds and postural sway data were acquired during the postural stability tests.

**Center of Mass (COM):** The center of body mass (COM) was measured while the participants were walking on 30 meter of unobstructed even floor, using 3D motion analysis system (VICON Motion System, VICON Ltd., England). Here, thirty nine 14mm reflective markers were attached to the participants to capture their walking motions, according to the plug-in gait marker sets.

**Foot Pressure Distribution (FPD) and Center of Pressure (COP):** FPD and trajectories of COP at both feet were measured while the participants were walking on 30 meter of unobstructed even floor, using insole pressure measurement system (Pedar X, Novel gmbh, Germany). The FPD and trajectories of COP were then measured with a sampling rate of 100 Hz.

**Statistical Analysis:** A paired t-test and one-way ANOVA test with Tukey's-b post hoc multiple comparisons were used to identify existence and nonexistence of statistically significant differences. Here, the significance levels for all statistical tests were set at 0.05.

### RESULTS AND DISCUSSIONS

The postural sway score of hemiplegia patients was moved towards the unaffected side while they are

in upright posture. The postural sway score of healthy male and elderly male were about 2 times greater than that of hemiplegia patients ( $p < 0.05$ ). COM of hemiplegia patients was more inclined to unaffected side than that of the other participants. In additional, COM of hemiplegia patients was more inclined to unaffected side during the swing phase (Figure. 1). The FPD patterns in both feet of healthy male and elderly male were similar with each participants. However, FPD patterns of unaffected side of hemiplegia patients were 1.2 times greater than that of affect side. The trajectories of COP of healthy male and elderly male were located entirely foot from calcaneus to toe. However, the trajectories of COP of hemiplegia patients were located from calcaneus to metatarsal bones. From the current study, these results are expected to use as the control function to secure gait stability for the balance transfer for hemiplegia patients.

### REFERENCES

Kelley R.E. *et al*, Neurol Res. 31:832-840, 2009.

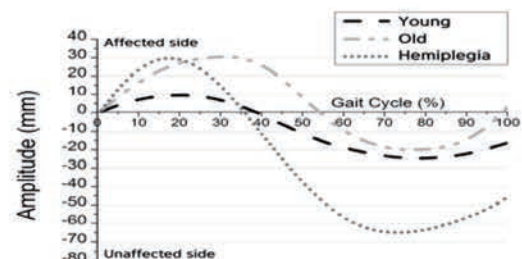


Figure 1. Comparison of trajectories of center of mass for normal health young and old people and hemiplegia patients

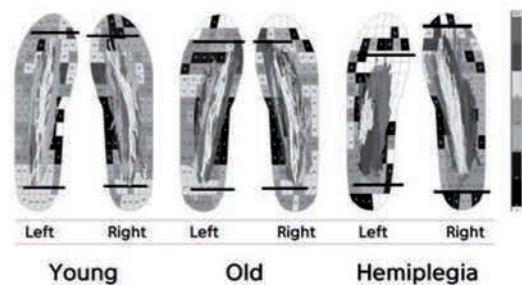


Figure 2. Foot pressure distribution and trajectories of center of pressure

## YES, WE CAN ... INFLUENCE FOOT LOADING PATTERNS BY DELIBERATELY WALKING WITH IN-TOEING OR OUT-TOEING GAIT MODIFICATIONS

Dieter Rosenbaum

Movement Analysis Lab, Institute for Experimental Musculoskeletal Medicine, University Hospital Münster, Germany

### INTRODUCTION

Congenital in-toeing gait patterns are often seen in children and are a predominant cause for parents to refer their children for orthopaedic consultation even though no other symptoms other than the 'strange appearance' are reported (Uden & Kumar 2012). Furthermore, out-toeing gait can often be observed in children with flat feet, seemingly aggravating the tendency to a pronounced medial loading and more hind-foot valgus.

The aim of this study was to analyze the effects of deliberate out-toeing and in-toeing on foot loading patterns in normal subjects. Potential findings might help to decide whether specific gait training might achieve changes in the foot progression angle in order to cause a desirable load transfer.

### SUBJECTS & METHODS

12 normal, healthy adults (6 male & 6 female, age  $39 \pm 12$  yrs., height  $176 \pm 7$  cm, weight  $70 \pm 12$  kg, BMI  $23 \pm 3$  kg/m<sup>2</sup>) with inconspicuous foot shapes and free of recent or chronic foot and lower extremity problems participated.

5 trials of barefoot walking were collected from each foot during normal (i.e.  $\pm$  straight), in-toed and out-toed walking on a capacitive pressure-sensitive platform (Emed X, Novel GmbH Munich). To ensure comparability, the approach and number of steps were kept constant in all three conditions.

The foot progression angle (FPA), arch index (AI) and regional foot loading parameters were determined with Novel Database Medical (v. 23.1.18).

### RESULTS

The three conditions showed a FPA of  $7 \pm 4^\circ$  for normal,  $-20 \pm 6^\circ$  for in-toeing and  $32 \pm 9^\circ$  for out-toeing ( $p < .0001$ ). This also changed the AI from  $0.157 \pm 0.078$  to  $0.187 \pm 0.064$  and  $0.148 \pm 0.085$ .

For in-toeing, the regional analysis indicated significantly lower peak pressures and force-time integrals in medial regions (PP -9% to -46%, FTI -5% to -42%) and higher values in the lateral mid- and forefoot (PP +33% & +59%, FTI +61% & +49%).

Out-toeing lead to reduced loading in the lateral mid- and forefoot (PP -7% to -38%, FTI -6% to -27%)

and higher loading in the medial hind-, mid-, forefoot and hallux (PP +16% to +64%, FTI +20% to +72%).

### DISCUSSION & CONCLUSION

The results support the clinical observations that out- and in-toeing gait may lead to characteristically altered foot loading patterns. While out-toeing enhances a medialized loading (as it is often seen in pes planovalgus), in-toeing slightly unloads the medial foot structures but shifts the load to the lateral mid- and forefoot. This raises the question whether these mechanisms might be applied for unloading specific high-load areas in patients with local pain or problems. However, it needs to be investigated that patients are able to deliberately alter their gait patterns and that this will not cause overloading in other regions or joint.

### REFERENCES

Uden & Kumar. J Multidiscipl Healthcare 2012;5 27–35

### ACKNOWLEDGEMENT

Sincere thanks to the subjects for their support.

Contact: [diro@uni-muenster.de](mailto:diro@uni-muenster.de)



# ARE THERE ANY RELEVANT PEDOBAROGRAPHIC CHANGES BELOW THE METATARSALS AFTER HALLUX VALGUS SURGERY? A SERIES OF LAPIDUS ARTHRODESIS AND ASSOCIATED METATARSAL OSTEOTOMIES

Albrecht. Dietze, Andre. Michel<sup>(2)</sup>, Thomas Mittlmeier

1. Chirurgische Universitätsklinik Rostock, Abteilung für Unfall- und Wiederherstellungschirurgie, Rostock, Germany
2. Orthopädische Klinik 2, Dietrich-Bonhoeffer-Klinikum, Malchin, Germany

## BACKGROUND

The hallux valgus deformity (hv) is a common mostly degenerative pathology of the foot with a wide range of treatment options. The tmt 1 (Lapidus) arthrodesis is a widely accepted surgical treatment option, which allows sufficient hv correction in the forefoot with limited opportunities to compensate the deformity as far as the hindfoot. Additionally metatarsal osteotomies of the 3rd-5th ray may be necessary to restore distal metatarsal realignment (chyma line) Pedobarography has become a valuable tool to objectively describe perioperative changes in foot surgery. Maximum force and force time integral are accepted measures for foot loading analysis and were therefore chosen as investigative criteria.

The goal of our study was to investigate whether lapidus arthrodesis and overlength correction of the remaining mainly 2cd and 3rd metatarsal in cases of associated clinical complaints could demonstrate relevant load changes below the metatarsals.

## MATERIAL AND METHODS

From the beginning of 2009 until the end of 2010 40 patient (mean age 50 years, range 26-75 years) with hv deformity of which 9 (six in the 2cd mt, three in the 2cd and 3rd mt) had associated metatarsal overlength in the 2cd and/ or 3rd mt who were selected for surgery were enrolled. Of all four were male and 36 were female. For objective perioperative status documentation hv specific radiological angles, the AOFAS score for clinical and functional results as well as an emed plantar loading analysis was performed (Novel, Munich, Germany). Pedobarographically the maximum force and force time integral were determined and analysed. The follow up investigation was around 12-14 months after surgery.

Statistical analysis of mean values was done by the t-test or Wilcoxon test and correlation analysis by the spearman test.

## RESULTS

The mean maximum force and force time integral were pre- and postop 165 N and 184 N as well as 74 N/s and 71 N/s respectively. In the 31 cases of isolated Lapidus arthrodesis the maximum force under the 1st metatarsal increased in 21 and decreased in 10 patients. The mean maximum force and force time integral values are shown in table 1 and 2 for all 3 subgroups. Our clinical and radiologic results showed significant improvement of the AOFAS score ( $p < 0.05$ ) and significant reduction of the radiologic angles ( $p < 0.001$ ) after hv correction.

## DISCUSSION

Perioperative pedobarography may help to objectively describe morphological changes due to corrective foot surgery additionally to clinical and radiographic findings. In the literature, varying load distribution pattern in patients with hv deformity and associated pathology (i.e. metatarsalgia) are stated. With our study we support the idea to objectively follow plantar loading changes to evaluate functional outcome in foot and ankle surgery.

Procedure	1st mt F-t Integral pre- /postop	2cd mt F-t Integral pre- /postop	3rd mt F-t Integral pre- /postop
Lapidus arthrodesis (n=31)	70/82 N/s	82/83 N/s	95/76 N/s *
Lapidus + Weil Osteotomy 2cd mt (n=6)	75/75 N/s	95/85 N/s	105/98 N/s
Lapidus + Weil Osteotomy 2cd and 3rd mt (n=3)	97/95 N/s	85/82 N/s	94/67 N/s

Table 1 Force time integral of the analysed groups (\* $<0,05$ )

Procedure	1st mt Fmax pre- /postop	2cd mt Fmax pre-/postop	3rd mt Fmax pre- /postop
Lapidus arthrodesis (n=31)	164/178 N*	164/190 N*	184/165 N *
Lapidus + Weil Osteotomy 2cd mt (n=6)	162/182 N	180/182 N	210/207 N
Lapidus + Weil Osteotomy 2cd- and 3rd mt (n=3)	195/271 N	162/193 N *	168/149 N

Table 2 Maximum force of the analysed groups (\* $<0,05$ )



## COMPUTATIONAL MODELING OF ERGOMETER ROWING

Rasmus Juliussen (1), Per Aagaard (2), Mark de Zee (3), John Rasmussen (4), Erik B Simonsen (1), Anders Vinther (5), Tine Alkjær (1)

1. Dept of Neuroscience and Pharmacology, University of Copenhagen, Copenhagen, Denmark.
2. Inst of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense.
3. Dept of Health Science and Technology, Aalborg University, Aalborg, Denmark.
4. M-Tech, Aalborg University, Aalborg, Denmark.
5. Dept Medicine O. Herlev Hospital and Dept Health Sciences, Lund University

### INTRODUCTION

Rib stress fractures are commonly observed in rowers and impair training and performance. These fractures keep the athletes out of training for 3-8 weeks. Further knowledge about the injury mechanism is needed to prescribe preventive interventions. In the present study the purpose was to design a computational model of ergometer rowing to investigate the rowing movement, and the forces generated in the shoulder/thorax region during stationary and slide-based ergometer rowing.

### FIGURES AND TABLES

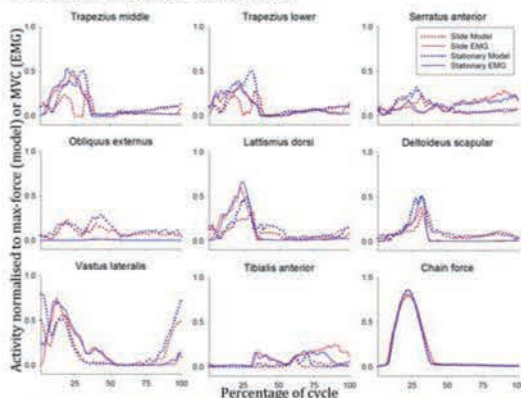


Figure 1: Estimated muscle forces and recorded EMG results for slide-based (red) stationary (blue) ergometer rowing. Solid lines are the EMG recordings and the dotted are the model results. The handle force (chain force) is shown in the right bottom corner.

### METHOD

#### Data collection

The analysis was based on the study by Vinther et al. [1] where 22 elite athletes from the Danish National Rowing team participated. They were asked to row in a Concept2 ergometer on slides, which were blocked to constitute the stationary trial. Motion data was obtained by five cameras operating at 50Hz, and then digitized using APAS. Electromyography (EMG) was recorded from eight muscles. The handle force produced during rowing was measured with a strain gauge. All the athletes were also DEXA scanned to determine body composition as well as segment lengths and masses.

#### Model building

The AnyBody Modeling System (ver. 5.0.1 AnyBody Technology, Aalborg, Denmark) was used to develop a computational model of ergometer rowing on the basis of experimental data from one representative rower. The marker trajectories from the video camera recordings were used to drive the kinematics of the computer model and the measured chain force was input in the model. The choice of marker setup, which comprised 18 points on the rower, and 11 on the ergometer, left some unconstrained degrees-of-freedom. Therefore adequate joint drivers and constraints were added to ensure that the model behaved in a physiological manner. The sterno-clavicular joint was fixed and the hand movement was constrained by the ergometer handle.

### RESULTS AND DISCUSSION

Figure 1 illustrates that the muscle forces estimated by the model match the EMG data quite well. The electromechanical delays are clearly visible in most of the muscles included here. Furthermore, there is a clear tendency to lower peak muscle forces in the trial on slides.

The results provided in the present study, may be applied to the theories presented by Warden et al. [2] and McDonnell et al. [3] regarding potential injury mechanisms. Thus, the Rib Cage Compression Theory [2] was tested, by quantifying the magnitude of compressional force exerted on the ribs. This showed a 39% reduction in the peak compression force.

The present results show that the muscle forces and magnitude of the compression force acting on the ribcage are reduced during slide-based ergometer rowing, compared to stationary rowing. Thus, slide-based ergometer rowing may be a commendable training device with respect to risk of rib stress fractures.

Knowledge of the muscle forces provided by the model can potentially be used along with knowledge of the mechanical properties of the bone structures to estimate the stress-fatigue impact on the ribs.

### REFERENCES

1. Vinther A, Scand J Med Sci Sports Jan. 31. 2012.
2. Warden et al, Sports Med 32(13):819-836, 2002.
3. McDonnell et al, Sports Med 41(11):883-901, 2011.

## RELATIONSHIP BETWEEN PRESSURE AND VERTICAL FORCE RELATED VARIABLES IN DIFFERENT RUNNING SHOE CONSTRUCTION TECHNOLOGIES

Roberto C. Dinato<sup>1</sup>, Ivye L. R. Pereira<sup>1</sup>, Kenji Butugan<sup>1</sup>, Ana Paula Ribeiro<sup>1</sup>,  
Andrea N. Onodera<sup>1,2</sup>, Isabel C. N. Sacco<sup>1</sup>

<sup>1</sup> Physical Therapy, Speech and Occupational Therapy dept, School of Medicine, University of São Paulo, Brazil.

<sup>2</sup> Biomechanics laboratory, DASS Sport & Style Inc., Ivoti, Brazil

### INTRODUCTION

The impact absorption capability of the sports shoes has been the subject of numerous studies over the years<sup>1, 3, 4</sup>. Biomechanical assessments have been made to determine the influence of sports shoes on impact-reducing, through different biomechanical variables, among which those related to plantar pressure distribution<sup>1, 4</sup> and ground reaction force<sup>5, 6</sup>. In the context of sports shoes performance assessment, the choice of a variable over another, can impede or facilitate the discrimination among different technologies for construction of athletic shoes available to recreational runners and different technologies for impact cushioning. The aim of this study was to investigate if the plantar pressure pattern and ground reaction force related variables during running can differentiate four different footwear construction technologies: *Air*, *Gel*, *Adiprene* and *EVA*.

### METHODS

We recruited and analyzed 19 male recreational runners with a rearfoot strike pattern, with minimum experience of one-year training, and with a running volume of at least 20km/wk (39.1±6.5 yr, 73.8±9.6 kg). The plantar pressure were collected using the in-shoe Pedar-X system and ground reaction force was measured using a force platform AMTI during overground running in 4 different commercially available sport shoe constructions (*Air*, *Gel*, *Adiprene* e *EVA*). The test speed was controlled by two photocells (3.3±5%ms). Pressure related variables were analyzed over rearfoot, midfoot and forefoot: relative load (LR), peak pressure (PP) and pressure-time integral (IP). Force related variables analyzed were: 1<sup>st</sup> vertical force peak (FPVF), 2<sup>nd</sup> vertical force peak (SPVF), loading rate “0 to 100% 1<sup>st</sup> peak” (LRVF), impact transient “20 to 80% 1<sup>st</sup> peak” (IT) and pushoff rate (POF). Pearson correlations were calculated to determine the association of dynamic pressure and force variables. It was adopted an  $\alpha=0.05$ .

### RESULTS

There was no association between pressure and force variables over the rearfoot among the four technologies ( $p > 0.05$ ). In the forefoot, we observed moderate and significant correlations between PP and POF in two different technologies: Air and EVA.

Table 1- Correlations between peak pressure (PP) over the forefoot and the 2<sup>nd</sup> vertical peak (SPVF) and push off rate (POF).

	SPVF	p	POF	p
PP shoe air	-0.30	0.21	<b>-0.48</b>	0.03*
PP shoe gel	0.23	0.34	-0.03	0.90
PP shoe adiprene	0.03	0.91	-0.24	0.32
PP shoe EVA	0.06	0.81	<b>-0.51</b>	0.02*

### DISCUSSION

In Air and EVA technologies, the lower the peak pressure in the forefoot, the greater push off rate. Such relationship seems to be advantageous, since there is a fast propulsion rate without higher pressures in the small area of the forefoot. Studies comparing different cushioning technologies found that the greater the usage time of the footwear, the lower its cushioning capacity, without changing ground reaction force variables. This fact suggests that an adaptation in the running style may occur to keep similar body loads even in a different cushioning condition<sup>2</sup>. In our study, the loading rate and plantar pressure in the rearfoot did not showed any relationship in any of the shoes analyzed. This result can also be explained by a possible adaptation in running style despite the footwear usage time<sup>2</sup>, but due to different cushioning technologies. Most of the literature describes pressure patterns and its associations to force variables during running for the mid and rearfoot areas<sup>2,7</sup>. Thus, our findings in the forefoot may add to the existing literature in a great extent.

### CONCLUSION

Shoes with EVA and Air technologies showed an inverse relationship between peak pressure and push off rate. It was not possible to identify through the correlation analysis a kinetic variable that distinguish the different cushioning technologies studied.

### REFERENCES

- 1- Clinghan, *et al*, Br. J Sports Med. 0:1-5, 2007
- 2- Kong, *et al*, J Sports Med. 43:745-749,2009
- 3- Hennig and Milani, J Applied Biom. 11:299-310, 1995
- 4- Dixon, 2008, Ergonomics, 1503-1514, 2008
- 5- Cavanagh e LaFortune, J Biomech 13(5): 397-406,1980
- 6- Lieberman, Nature, 2010
- 7- Milner, *et al*, Med. Science Sports Exer., 2006



## PEDOBAROGRAPHICAL FINDINGS AFTER OPERATIVE ANKLE FRACTURE TREATMENT PRELIMINARY RESULTS– A PROSPECTIVE CLINICAL TRAIL

Andreas. Annecke, Albrecht. Dietze, Thomas Mittlmeier

Chirurgische Universitätsklinik Rostock, Abteilung für Unfall- und Wiederherstellungschirurgie, Rostock, Germany

### BACKGROUND

Pedobarography serve as an objective and quantitative evaluation method for perioperative foot function. Its application in the field of foot and ankle surgery may help to demonstrate structural and functional changes after ankle trauma care. In our study, we evaluated plantar pressure pattern changes after surgery. We compared postoperative preliminary findings due course twice in simple and complex ankle fractures.

### MATERIAL AND METHODS

In our study 13 patients (female, 6; male, 7) had completed 2 pedobarographic follow up visits and were divided in two groups based on the complexity of the present ankle fracture (group 1, simple lateral malleolus fracture, mean age  $50.3 \pm 14.2$ ; group 2; complex ankle joint fracture, mean age  $53.5 \pm 9.1$ ). The follow up was performed included a clinical examination with AOFAS-score determination and available x-rays were reviewed. The pedobarographical analysis was undertaken with a plantar pressure measurement platform (Novel, Munich, Germany). Maximum force [mf], peak pressure [pp], force time integral [fti], contact time[tc] and maximum speed [vm] were determined for the whole foot, fore-, mid-, and hind foot. Statistical analysis of mean values was done by the t-test or wilcoxon test, correlation analysis by the spearman test.

### RESULTS

As a result of a correlation analysis, for the simple fracture group at first (147 days postop) and second (272 days postop) follow up visit comparing the injured with the non injured side walking speed as well as total- and hindfoot pp and fmax were relevantly reduced. Due course (2cd visit) hindfoot pp and fmax had the tendency to normalize.

For the group of complex fractures walking speed, contact time (mid foot significantly  $p=0.03$ , mean value comparison) and total- and hindfoot pp and fmax showed also relevant reduction after the 1<sup>st</sup> (146 days) On the 2cd visit (310 days postop) of follow up hindfoot pp and fmax improved towards the values of the nonoperated side.

For the other variables, no significant differences were found.

### DISCUSSION

By pedobarography weight bearing and additionally regional foot loading can be well detected. Although we overlook a rather small series of patients we believe to have found relevant trends for postoperative foot load bearing. Based on our findings the patients with more complex ankle fracture presented a more modest course of foot loading than those with simple lateral malleolus fractures. Our findings confirm our clinical observation of a prolonged rehab time for patients after surgical treatment of complex ankle fractures. Furthermore our investigation series will be enlarged to obtain more reliable data and to provide references to may objectively comment on functional status by pedobarography.



# STATIC ARCH HEIGHT AND REARFOOT ALIGNMENT ARE ASSOCIATED WITH DYNAMIC PLANTAR PRESSURE PATTERNS DURING RUNNING IN RUNNERS WITH PLANTAR FASCIITIS

Ana Paula Ribeiro, Sílvia M.A. João, Isabel C.N. Sacco

Physical Therapy, Speech and Occupational Therapy Dept, School of Medicine, University of São Paulo, Brazil.

## INTRODUCTION

Changes in dynamic foot loading due high or low plantar arch have been associated with many overuse injuries in lower limbs<sup>1,2,3,4</sup>. Foot alignment is another important property which may alter plantar distribution pattern of the foot<sup>5</sup>. However, most of these association was performed during gait<sup>6,7,8</sup> and their results show an association between plantar arch and force, pressure-time integral<sup>8</sup> and pain in rearfoot<sup>6</sup>. There is still a lack of evidence of these associations during running, especially in subjects affected by foot injuries, such as plantar fasciitis. The only study that investigated this type of association during running reported that the rearfoot alignment was a good predictor of maximum plantar pressure and pressure-time integral over medial rearfoot and midfoot in healthy pain free runners<sup>9</sup>. According to Teyhen *et al.* (2009)<sup>8</sup>, further studies are needed to investigate the association between extremely high plantar arch and dynamic plantar pressure patterns in pathological conditions. Most of the descriptive results in the literature showed that runners with plantar fasciitis show a high plantar arch<sup>10,11</sup>. Therefore, the purpose of this study was to investigate the association between plantar arch and rearfoot alignments and dynamic plantar pressure related variables in runners with plantar fasciitis (acute and chronic).

## MATERIALS AND METHODS

Forty-five recreational runners with diagnosed plantar fasciitis (by US) were evaluated: 30 in the acute phase of the disease with foot pain (APF) (45.4±8.1 yr, 69.6±14.0 kg, 1.68±9.2 m) and 15 in the chronic phase without foot pain (CPF) (38±3yr, 72.3±10.0 kg, 1.8±0.8 m). The pain was evaluated using a Visual Analogue Scale. The assessment of rearfoot alignment<sup>12</sup> and the arch height index calculation (AHI)<sup>13</sup> were performed in digital images<sup>10</sup>. The plantar pressure was evaluated by Pedar X system during running in a 40 meters track at 12±5% km/h. Runners used a standardized sport footwear. All runners exhibited a heel strike pattern of running. The impact transient and loading rate were estimated by plantar pressure time series. Force, force-time integral, peak pressure, maximal mean pressure, pressure-time integral and contact area were evaluated over the rearfoot, midfoot and forefoot. The data were processed in a custom written Matlab function. A significant Pearson correlation ( $p<0.01$ )<sup>7</sup> was used to reduce the number of variables of interest. A stepwise forward regression analysis was performed to predict group of dependent variables of pressure, area, force, impact transient from the AHI and the rearfoot alignment [independent variables]. Dependent variables were sequentially entered in three blocks ( $p<0.05$ ).

## RESULTS

The APF group showed a mean pain of 7±2 consecutive months and an intensity of 5±2 cm. The mean AHI<sup>13</sup> was 0.185±0.06 for APF and 0.171±0.07 for CPF. The mean rearfoot alignment was 8.0±3.1 degrees for APF and 6.6±4.3 degrees for CPF. Pearson product moment correlation ( $p<0.05$ ) yielded 20 variables resulted in 13 variables of interest. Seven variables were removed from the model based on multicollinearity. Variables related to area in midfoot, force and force-time integral, pressure (maximal and integral) over the rearfoot, midfoot and forefoot remained in the final model. Smaller contact area of the midfoot and higher force in the forefoot were associated with a higher AHI in APF ( $p<0.05$ ;  $R^2$ : 0.58; 0.48, respectively) and a higher force-time integral in the rearfoot were associated with a higher AHI in CPF ( $p<0.05$ ;  $R^2$ : 0.38). The rearfoot alignment was associated with a lower maximal mean pressure and pressure-time integral in the midfoot in APF ( $p<0.05$ ;  $R^2$ : 0.56; 0.48) and increase force of the midfoot in CPF ( $p<0.05$ ;  $R^2$ : 0.64).

## CONCLUSION AND DISCUSSION

The static AHI and rearfoot alignment were able to predict the dynamic plantar pressure parameters in runners in different stages of plantar fasciitis. These can be summarized as follows: (1) in runners with pain (APF group), higher arches predicted a smaller midfoot contact area and a higher forefoot force and static valgus rearfoot alignment predicted a lower midfoot peak pressure; (2) in runners without pain (CPF), higher arches predicted a higher rearfoot force and static valgus rearfoot alignment predicted a higher midfoot force. Lee and Hertel (2011)<sup>9</sup> also observed an association between rearfoot misalignment and an increased force in the midfoot. The predictions and associations of our study may suggest that the treatment with insole for plantar arch correction and rearfoot realignment could be more appropriate in the chronic phase of plantar fasciitis (without pain) aiming at decreasing rearfoot pressure and preventing pain recurrence.

## REFERENCES

1. Burns, Keenan and Redmond. JAPMA 95: 235-240, 2005a.
2. Hreljac, Marshall, Hume. Med. Sci Sports Exerc. 32: 1635-41, 2000.
3. Kaufman *et al.*, Am. J. Sports Med. 27: 585-593, 1999.
4. Williams *et al.* Clin Biomech. 16: 341-47, 2001.
5. Sarrafian, S. Foot & Ankle. 8:4-18, 1987.
6. Burns *et al.* Clin Biomech. 20: 877-82, 2005b.
7. Wong *et al.* JAPMA. 98: 112-17, 2008.
8. Teyhen *et al.* Clin Biomech. 24: 391-396, 2009.
9. Lee and Hertel. J Sport Rehabil. 15, *in press*, 2011.
10. Ribeiro *et al.* Clinics. 66(6): 1027-1033, 2011.
11. Taunton *et al.* J Sports Med. 36: 95-101, 2002.
12. McPoil and Cornwall. Br J Sport Med. 23: 370-375, 1996.
13. Cavanagh and Rodgers. J Biomech. 20: 547-551, 1987.

## INTEGRATED GAIT ANALYSIS OF FLATFOOT: THE POTENTIAL OF APPROPRIATE FOOT MODELS AND ANATOMY-BASED PEDOGRAPHY

Claudia Giacomozzi (1), Julie Stebbins (2), Lisa Berti (3), Alberto Leardini (3)

1. Dept. Of Technology and Health, Italian National Institute of Health (ISS), Rome, Italy
2. Nuffield Orthopaedic Centre, Oxford, UK
3. Istituto Ortopedico Rizzoli, Bologna, Italy

### INTRODUCTION

Even though the dissemination of the pressure-force-kinematics integrated approach to foot investigation during gait started several years ago (Giacomozzi 2000; Stebbins 2005), its effective and wide-spread use in research and in the clinics is still debated. This study aims at supporting two major hypotheses for the methodology to be successfully deployed: i) it is reproducible and applicable to different equipment scenarios and foot models; ii) appropriate foot model and anatomy-based regionalization of the foot represent an added value in the biomechanical analysis of foot pathologies. To support the latter hypothesis, a valuable example is presented here with respect to flatfoot.

### MATERIALS AND METHODS

**Methodological aspects.** The Gait Labs of the Oxford Nuffield Orthopaedic Centre (ONOC) and of the Istituto Ortopedico Rizzoli in Bologna (IOR) were involved in the study. Equipment included two different Motion Capture Systems by Vicon, two different EMED pressure plates by novel gmbh, AMTI force plates in the former, Kistler in the latter, 14mm and 10mm reflective markers respectively, validated foot models (Stebbins 2006, Leardini 2007). Methodology for 5-regions anatomical masking of pedographic data was similar in both centres and was implemented in an original novel software for one medio-lateral and one longitudinal masking. Foot models were compared, and validation tests conducted on healthy volunteers.

**Clinical application.** Flatfeet were investigated. The most appropriate foot model and anatomical masking were identified, and some preliminary tests were performed on three patients with mild to severe flatfoot deformity. These were equipped with the proper set of markers and asked to walk in a sequence of level walking, walking on the toes, walking on the heels, and slow running.

### RESULTS

**Methodological aspects.** The marker placement was almost fully comparable for the two foot models, the main difference being the position of the marker on the base of the 5<sup>th</sup> metatarsal: on the bony prominence in ONOC, on the joint line in IOR model (Fig.1). Differences in regional parameters were

negligible in both the medio-lat and the longitudinal masks except for the midfoot region (5-10%). Random displacement of markers in the range  $\pm 5$ mm resulted in negligible variations of all kinetic parameters, too.



Figure 1: superimposition of marker placement as for the IOR (black) and the ONOC (red) model

**Clinical application.** The IOR model, and the longitudinal anatomical masking, were found to be the most appropriate to investigate flatfoot because of the better identification of the midfoot. In one patient the flatfoot condition resulted in midfoot and forefoot contact and loading even during heel walking (Fig.2).

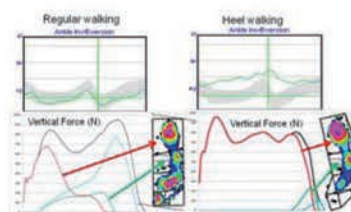


Figure 2: ankle inversion/eversion (upper part) and vertical force curves associated with hindfoot, midfoot and forefoot in two walking conditions.

### DISCUSSION AND CONCLUSIONS

The proposed integrated approach proved to be reliable and reproducible under different experimental scenarios and in association with different foot models and sub-division criteria. It proved to be a valuable tool in the clinics, i.e. in flatfeet, where it showed great potential in quantifying regional loading variations associated with altered kinematics; unlike geometry-based regionalization of the footprint, it allowed direct comparisons among different walking tests even when implying incomplete footprints.

### REFERENCES

- Giacomozzi *et al*, MBEC, 38(2):156-63, 2000.
- Giacomozzi *et al*, ESM2010 workshop on "3D motion capture systems and pedography".
- Leardini *et al*, G&P, 25(3):453-62, 2007.
- Stebbins *et al*, G&P, 22(4):372-6, 2005.
- Stebbins *et al*, G&P, 23(4):401-410, 2006.



## PLANTAR PRESSURE DISTRIBUTION DURING WALKING IN HABITUALLY BAREFOOT POPULATIONS

Roshna E. Wunderlich<sup>1</sup>, Kevin G. Hatala<sup>2</sup>, Heather L. Dingwall<sup>2</sup>, Brian G. Richmond<sup>2,3</sup>

1. Department of Biology, James Madison University, Virginia
2. Center for the Advanced Study of Hominid Paleobiology, Department of Anthropology, The George Washington University, Washington D.C.
3. Human Origins Program, National Museum of Natural History, Smithsonian Institution, Washington D.C.

### INTRODUCTION

Considerable evidence suggests that modern footwear influences foot shape, foot function, and possibly foot deformity (e.g. Ashizawa, 1997; Rao *et al.*, 1992; Zipfel and Berger, 2007). Understanding fundamental characteristics of foot function during walking as well as human variation in foot function during walking requires examination of individuals who have never worn shoes. The recent discovery of 1.5 million-year-old hominin footprints near Ileret, Kenya offers the opportunity to analyze the earliest development of the human foot but has also highlighted the importance and the paucity of quantitative pedal biomechanics data on humans whose feet have not been influenced by modern footwear. To date, only D'Août *et al.* (2009) have quantified plantar pressure distribution in a broad comparison of foot shape and relative foot pressures in a habitually unshod Indians population.

unshod vs. shod populations. In particular, metatarsal and heel peak pressures are reduced in unshod populations. These differences may be due to morphological (soft tissue, foot width (Ashizawa *et al.*, 1997; D'Août *et al.*, 2009) or kinematic features facilitating the attenuation of high loads (e.g., Lieberman, 2010; Robbins, 1991).

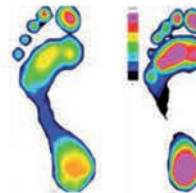


Figure 1: Characteristics peak plantar pressures in (left) habitually unshod individual from southern Madagascar and (right) habitually shod individual from the U.S.

### METHODS

We examined plantar pressure distribution in two populations, both unshod or minimally shod, and one population of healthy shod western adults. 28 adults from Mahajoroivo, Madagascar, 19 adults from Ileret, Kenya, and 295 adults from the U.S. walked barefoot across a plantar pressure mat (EMED in Madagascar; RSScan in Kenya) at a self-selected pace. Video was collected for kinematic analysis, and steps were compared within a restricted speed range. Data were compared across groups using ANOVA with Tukey's HSD.

### RESULTS AND DISCUSSION

Peak pressures were generally lower in unshod populations than in shod populations. In particular, significantly lower pressures in the medial heel, all metatarsals, and first toe in both unshod populations compared to the shod group. However, differences were also observed between the unshod populations. The unshod Malagasy population exhibited lower lateral heel and lateral midfoot pressures than the unshod/minimally shod Daasanach.

Our data support D'Août *et al.* (2009) in demonstrating overall lower peak plantar pressures in

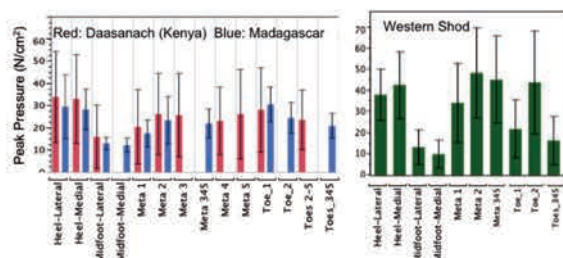


Figure 2: Regional peak plantar pressures in (left) habitually unshod populations from Kenya and Madagascar and (right) shod westerners.

### REFERENCES

- Ashizawa *et al.*, Annals of Human Biology 17(2): 117-129, 1997  
 D'Août *et al.*, Footwear Sci 1(2): 81-94, 2009.  
 Frey *et al.*, Foot and Ankle 14(2):78-81, 1993.  
 Rao *et al.*, J Bone Jt Surg 74B(4): 525-527, 1992.  
 Zipfel and Berger, The Foot 17: 205-213, 2007.



## A SIMPLE SCALING RELATIONSHIP FOR CPEI BETWEEN THE EMED-X AND MATSCAN

Loretta Cacace (1, 2), Jocelyn Hafer (2), Mark W Lenhoff (2), Jinsup Song (3),  
Marian T Hannan (4), Howard J Hillstrom (2, 3)

1. Hunter College, New York, USA
2. Hospital for Special Surgery, New York, USA
3. Temple University School of Podiatric Medicine, Philadelphia, PA
4. Hebrew Senior Life, Boston, USA

### INTRODUCTION

Center of Pressure Excursion Index (CPEI) is a measure of dynamic foot function that assesses the concavity of the center of pressure curve in the metatarsal head region, normalized to foot width during the stance phase of gait (Song et al, 1996). In a recent study that evaluated 61 asymptomatic test subjects (122 feet) (Hillstrom, 2012) CPEI values differed significantly among individuals with cavus (high arched) and planus (low arched) as well as planus and rectus (normal arched) foot types. Each test subject, ages 18-77, walked at their self-selected walking speed across a Novel emed-x plantar pressure measuring device (4 sensors/cm<sup>2</sup>). CPEI values of 20.2% or less were classified as planus while those over 22.9% were classified as cavus. In an ongoing epidemiological study of foot pathology and disability directed by Marian T Hannan, DSc, MPH, a database of over 3000 test subjects and their plantar pressure distributions has been collected using the TekScan MatScan (1.4 sensors/cm<sup>2</sup>). Due to the different resolutions it is not possible to directly apply thresholds distinguishing foot types from one system to the other. This project was undertaken to examine the scaling relationship for CPEI between these different plantar pressure measurement technologies.

### METHODS

Plantar pressure data from 22 asymptomatic subjects was recorded using two Tekscan Matscan devices and two Novel emed-x devices on the same day at the Leon Root, MD Motion Analysis Laboratory of the Hospital for Special Surgery (HSS). Ten trials of plantar pressure data were captured for each subject on each of the four measurement systems. Intra-class correlation coefficients (ICC(2,1)) were >0.7 for all intra and inter mat comparisons for all parameters. It was also determined for each parameter that the average of 5 trials provided an estimate ≤10% of the unbiased mean. When calculating CPEI from different technologies (e.g. emed-x and MatScan) the actual magnitude, which is expressed as a % of foot width, may differ due to accuracy and resolution differences. Simple linear regression models were created assessing the relationships between each of the four Matscan and emed-x devices. Slopes (unstandardized beta), y-intercept, and R<sup>2</sup> values were

calculated. The CPEI<sub>emed-x</sub> threshold value for distinguishing planus versus non-planus (rectus and cavus) feet was scaled to a CPEI<sub>MatScan</sub> threshold using this relationship. The relationship was tested by comparing MatScan classifications of planus vs non-planus foot types to that of the emed-x system on the same 22 test subjects (44 feet).

### RESULTS AND ANALYSIS

In order to scale CPEI between the two technologies, slopes and betas from each linear regression were averaged to formulate an equation to predict CPEI<sub>TekScan</sub> from CPEI<sub>emed-x</sub> values.

$$\text{CPEI}_{\text{TekScan}} = 0.85(\text{CPEI}_{\text{emed-x}}) + 2.40 \quad (1)$$

The CPEI threshold value distinguishing planus versus non-planus foot types was determined for the Tekscan Matscan system using the CPEI emed-x threshold from the previous study of foot types. The CPEI threshold value discriminating planus from non-planus individuals on a TekScan MatScan system is 19.4%. The 22 patients from this study were then classified as planus or non-planus in accordance with their emed-x CPEI data employing the threshold value of 20.2%. In addition, these same subjects were classified with the TekScan Matscan CPEI values using the scaled threshold of 19.4%. Planus versus non-planus individuals established by the TekScan Matscan threshold had a 94% correct classification with respect to the emed-x system. This supports using equation 1 for scaling CPEI values between these technologies for distinguishing planus vs. non-planus feet.

### DISCUSSION

A simple linear scaling relationship for CPEI was established between MatScan and emed-x technologies to permit analyses and comparison of results between these systems.

### REFERENCES

- Song et al, JAPMA, vol 86, No. 1, pp 16-23, 1996.  
Hillstrom et al, GCMAS, 2012  
Hillstrom et al, ESM 2008

### ACKNOWLEDGEMENTS

NIH R03HD053135-01; R01 AR047853-06

## BALANCING BAREFOOT IN SINGLE LEG BALLET POSES GENERATES LESS CENTER OF PRESSURE OSCILLATIONS

PAULA H. LOBO DA COSTA (1), FERNANDA G. S. A. NORA (1), MARCUS F. VIEIRA (2), KERSTIN BOSCH (3), DIETER ROSENBAUM (3)

1. Department of Physical Education, Federal University of São Carlos, Brazil.
2. Faculty of Physical Education, Federal University of Goiás, Brazil.
3. Institute for Experimental Musculoskeletal Medicine, University Hospital Münster, Germany.

### INTRODUCTION

Ballet dancing is a school of strong traditions. Some impressive moments in choreography occur when a dancer performs a balanced pose and holds the position for seconds. During the completion of these poses, the dancer tries to maintain stability by whole body adjustments while forces are transferred through the foot to the ground. The purpose of this study was to describe the effects of shoe conditions and lower limb positioning on stability demands of selected single leg poses of classical ballet.

### METODOLOGY

Fourteen female ballet dancers aged between 15 and 25 years, without any musculoskeletal pain and injuries that have practiced ballet for at least 7 years volunteered to participate in this study. The research protocol was approved by the Ethics Committee of the university (process number: 4060/2010). A capacitive pressure platform (EMED ST 4, Novel, Germany) at 50 Hz sampling rate and spatial resolution of four sensors per square centimeter allowed the assessment of center of pressure variables related to the execution of three single leg ballet poses: *attitude devant*, *attitude derrière* and *attitude a la second*. Center of pressure (COP) oscillation areas, anterior-posterior and medio-lateral COP oscillations and velocities were compared between two shoe conditions (barefoot versus slippers) and among the three different ballet poses. A custom-written Matlab code (The MathWorks Inc., USA) was used to compute and process COP variables in order to determine the overall degree of postural demands in the different conditions. The averaged data of three successful trials were used in the analysis. For statistical analysis, the Statistical Package for Social Sciences (SPSS for Windows 10.01, IBM, USA) was used. The variables were first tested for normality with Kolmogorov-Smirnov and Shapiro-Wilk tests. A two-way Analysis of Variance for repeated measurements for the position factor with Bonferroni adjustments for multiple comparisons was applied to the normally distributed data of COP variables (area and anterior-posterior and medio-lateral oscillations and velocities). The significance level was determined for  $p \leq 0.05$ .

### RESULTS

COP oscillation areas were significantly smaller for barefoot performances than with slippers for *attitude devant* ( $p < 0.00$ ) and *a la second* ( $p = 0.04$ ), but not for *attitude derrière* ( $p = 0.98$ ). Anterior-posterior COP oscillations were also significantly smaller for barefoot performances than when the poses were performed with slippers for *attitude devant* ( $p < 0.00$ ) and *a la second* ( $p = 0.02$ ), but not for *attitude derrière* ( $p = 0.92$ ). There were no significant differences between barefoot performances and performances with slippers for medio-lateral COP oscillations and velocities. Among the positions, *attitude derrière* produced significantly larger areas of COP oscillations and the largest anterior-posterior COP oscillations when performed barefoot. Anterior-posterior COP oscillations were significantly smaller for *attitude a la second* regardless of foot condition. Furthermore, medio-lateral COP velocity was the lowest for *attitude a la second* when performed barefoot and with slippers. Yan et al.<sup>9</sup> (2011) recently highlighted the possibility that dance footwear could restrict foot motion and our results suggest that the use of slippers may have slightly compressed the feet and limited to some extent the postural adjustments to maintain body verticality.

### CONCLUSION

Barefoot performances produced more stable poses for *attitude devant* and *attitude a la second*. Foot condition did not affect COP velocities. The different poses tested influenced the stability conditions and thus we can state that *attitude a la second* is the least challenging and *attitude derrière* is the most challenging of the poses tested.

### REFERENCE

Yan *et al.* J Dance Med Sci 15(2): 86-92, 2011.



## MEASUREMENT ACCURACY IS RELATED TO A HOMOGENOUS PRESSURE DURING THE CALIBRATION

Karsten Engel (1), Torsten Hübner (2), Wolfgang Potthast (1,3),  
Gert - Peter Brüggemann (1)

1. Institute of Biomechanics and Orthopedics, German Sport University Cologne, Germany
2. Department of Mathematics and Technology, RheinAhrCampus Remagen, Germany
3. Department of Sport and Sport Sciences, Karlsruhe Institute of Technology, Germany

### INTRODUCTION

Knowledge about the pressure distribution in the human knee joint and the force transfer are essential to better understand the progress of joint diseases. Two pressure distribution measurement systems, the capacitive Pliance system (Novel GmbH Munich, Germany) and the resistive Iscan® system (Tekscan Inc., Boston, USA) are commonly used in biomechanical and medical studies (Potthast, 2008, Li, 2004). Several studies on the accuracy of both systems used metal indenters, covered with rubber-like material for calibrations (Martinelli, 2006, Brimacombe, 2009). The problem using this setup is an overestimation in the centre and an underestimation near the border (Fig 2). Homogenous pressure applied to the sensor matrix is needed for a calibration and a valid statement on the systems accuracy. A new method that applies homogenous pressures to the sensors was developed. The purpose of this study was to investigate the systems accuracy using a homogenous pressure distribution.

### MATERIALS AND METHODS

The Novel Kneepad D and the Tekscan® K-Scan 4000 were used in our tests. A new pressure vessel (PV) filled with gel, normally used in ultrasonography diagnostics, ensured homogenous pressures (Fig. 1).

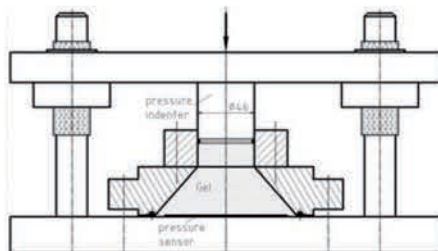


Figure 1: Pressure vessel to generate a homogenous pressure distribution.

A material testing machine (Zwick 020, Zwick GmbH Ulm, Germany) generated loads for the calibration and the measurements. After calibrating of both sensors up to 2.0 MPa following the manufacturers recommendations, four set pressures (0.5, 1.0, 1.5, 2.0 MPa) were

applied. Loads were increased over 5s, hold for 5s and decreased over 5s with ten repetitions for each set pressure stage. Means over three second from the maximum pressure were used to calculate the deviation between set and measured pressure.

### RESULTS

We could achieve a homogenous pressure distribution compared to the loading using indenters resulting in lower divergences in the borders of the sensors.

Set pressure	K-Scan	Pliance
0.5 MPa	41.6 %	5.5 %
1.0 MPa	33.2 %	1.1 %
1.5 MPa	15.7 %	1.7 %
2.0 MPa	1.0 %	2.6 %

Table 1: Calculated deviations from the set pressure

We found higher mean deviations from the set pressure for the K-Scan than for the Pliance system.

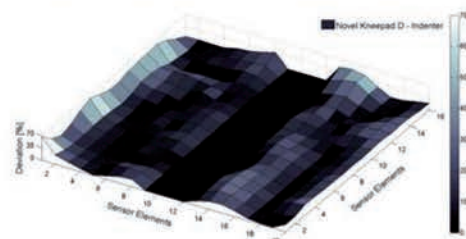


Figure 2: Inhomogeneous distribution using indenters

### DISCUSSION

The K-Scan system had to be set to the highest sensitivity level in order to detect pressures lower than 1.0 MPa. Using a homogenous pressure distribution for calibration leads to more precise results in the measurements. The Pliance system is more accurate in detecting pressures and less sensitive to the pressure surrounding.

### REFERENCES

- Brimacombe *et al.*, J Biomech Eng 131, 2009.  
Li *et al.*, J Orthopaed Res 22: 801–806, 2004.  
Martinelli *et al.*, Clin Orthop 447: 214–220, 2006.  
Potthast *et al.*, Clin Biomech 23: 632–639, 2008.



## BENCH PRESS WITH AN UNSTABLE LOAD DOES NOT AFFECT STABILITY

Mathias V. Kristiansen(1), Silas M. Svarrer(1), Mark H. Mora-Jensen(1), Andreas R. Timm(1)

1. Dept. of Health Science and Technology, Aalborg University, Denmark

### BACKGROUND

Numerous studies have investigated instability in relation to resistance training (Anderson, 2004; Langford, 2007). Different implements have been used to create either an unstable surface or load. However, no previous studies have tested instability in the bench press exercise with an unstable load.

The purpose of this study was to investigate effects on strength and stability, measured as center of pressure(COP) and barbell trajectory, following 4 weeks of linear periodized bench press training with equated volume.

### METHODS

Fourteen untrained to moderately trained young men volunteered for participation in this study and gave their written consent.

The subjects were divided into two groups using a relative strength index. Following a familiarization test, the subjects completed a 4 week training program with two sessions per week, in either normal bench press (NBP) or unstable bench press (UBP) conditions. Instability was created by suspending two 10 kg discs in rubber bands on either side of the barbell. Each subject completed three tests carried out in the week before training (Pre-test), at the beginning of week 3 (Mid-test) and in the week following the last training (Post-test). During tests each subject performed a 1 repetition maximum (1RM) and 3 repetitions on 80 % of 1RM with both stable and unstable barbell.

COP was obtained using a custom made standard flat bench (length: 122 cm, width: 32 cm and height: 45 cm) mounted on top of a force plate (Bertec Corporation 2003, UK).

Kinematics data was acquired using three 3D kinematic cameras (Qualisys, ProReflex MCU 240, Sweden).

### RESULTS

We found a significant increase in 1RM of 3.2% for both groups. Stability remained unchanged. A significant difference in the time to complete the lift was detected in the 3 rep and 3 rep unstable post test, with the UBP displaying the shorter time.

### DISCUSSION

Unstable bench press could be used as an alternative method to increase strength in the bench press. Furthermore, the use of a pressure distribution sensitive gauge, like the I-force glove (Lee, 2008), could reveal possible differences in the forces exerted in the hand. This could provide further data on the differences between doing bench press with a stable and an unstable load, in terms of stability demands.

### FIGURES



Figure 1: Suspension of a 10kg metal disc in the rubber band in order to create an unstable load.



Figure 2: Experimental setup

### REFERENCES

- Anderson KG. J strength and conditioning research 18: 637, 2004.
- Langford GA, J strength and conditioning research 21: 1061, 2007.
- Jung-Hyun Lee *et al*, International Conference on Control, Automation and Systems, ICCAS 2008

## Studded and Bladed Football Boots: Which One to Trust?

Tanveer S Bhutani (1), Graham P. Arnold (1), Sadiq Nasir (1), Weijie Wang (1), Rami. J. Abboud (1)

(1) Department of Orthopaedic and Trauma Surgery, Institute of Motion Analysis Research (IMAR), TORT Centre, University of Dundee, Scotland

### ABSTRACT

#### Introduction

Football is one of the most popular team sports in the world. It is also a highly competitive sport, and equipment manufacturers are continuously trying to improve and modify the equipment to enhance players' abilities and performance. One such advance was introduction of chevron shaped 'blades' to replace the traditional 'studs' in football boots. This has caused considerable controversy, with some studies suggesting higher injury rates and risk of metatarsal fractures to players who use 'bladed' boots.

#### Aims

Our study aims to biomechanically assess the effects of bladed and studded Nike® football boots by measuring the in-shoe plantar pressures to evaluate whether one cleat design offers an advantage compared to the other, and more importantly, if either can be potentially harmful. Phase 1<sup>1</sup> of this study has already been concluded.

#### Materials and methods

After obtaining ethical approval, the study was carried out by recruiting healthy, male volunteers from local amateur football and rugby teams. Inclusion criteria were age between 18 and 45, shoe size between UK 8 and 10, and regular participation in football. Exclusion criterion was any injury or surgery to lower limbs or back. Football boots chosen were studded Nike® TIEMPO LEGEND IV and bladed Nike® T90. Synthetic turf was chosen to be used in a lab to provide consistency in data recording. The in-shoe plantar pressures were measured using the Pedar®-X system. Velocity of the subjects was measured using the Vicon® motion analysis

system, using skin markers on the shoulders, the anterior superior iliac spines and on the C7 vertebra. After informed consent, anthropometric measurements were taken. Subjects were then asked to perform three straight trials of walk with both shoe types. Similarly, three trials were done each of straight runs and slalom (oblique cutting motion at 60°). For each trial, peak pressure (PP) measurement and pressure-time integral (PTI) were calculated over 11 pre-identified masked areas on the foot.

#### Results

Based on the data collected from the 18 subjects, the results suggest that with blades, there is a higher incidence of peak pressure (PP) over lateral midfoot and lesser metatarsals. Pressure-time integral (PTI) values are also consistently higher under the lateral part of the foot with bladed football boots. The mean instant of peak pressure (IPP) values were higher for blades during all trials as compared to studs. The values were higher and statistically significant for blades over head of first metatarsal and toes.

#### Discussion

The data supports the outcomes of Phase 1<sup>1</sup> study and suggests that bladed football boots may predispose players to higher plantar pressures and risk of stress fractures of the lateral midfoot and metatarsals. This suggests that the studied bladed football boots may potentially be harmful.

#### Reference:

1) Bentley JA, Ramanathan AK, Arnold GP, Wang W, Abboud, RJ (2011). Harmful cleats of football boots: A biomechanical evaluation. *Foot and Ankle Surgery*; 17: 140-144.



## SENSITIZATION AND DEGENERATIVE CHANGES IN THE TIBIOFEMORAL JOINT INFLUENCE PLANTAR LOADING IN PATIENTS WITH SYMPTOMATIC TIBIOFEMORAL OSTEOARTHRITIS

T. Røslund (1), L. S. Gregersen (1), T. N. Eskehave (1), L. Arendt-Nielsen (2), U. G. Kersting (2)

1. Department of Health Science and Technology, Aalborg University, Denmark
2. Center for Sensory-Motor Interaction, Department of Health Science and Technology, Aalborg University, Denmark

### BACKGROUND

Tibiofemoral osteoarthritis (OA) is a major cause of disability in the elderly population (Felson, 2009), and mechanical loading of the knee may be related to the progression of the disease (Henriksen et al., 2006). The distal body segments, such as the ankle and feet, affect the loading of the knee, as they transmit the ground reaction forces (Lidtkje et al., 2010). Therefore, this study investigated the plantar pressure of individuals with painful tibiofemoral OA. The current study sought to determine whether painful tibiofemoral OA is associated with aberrant loading across the foot during walking and whether this is correlated to the degree of degenerative changes and the intensity of pain and sensitization.

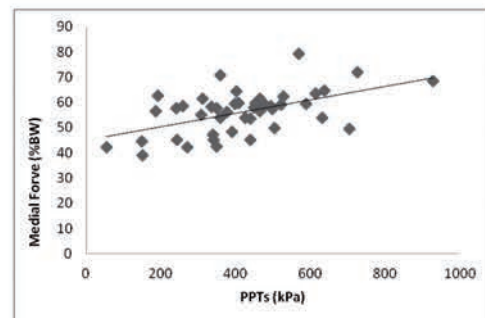
### METHODS

Fifteen knee OA patients with moderate peak knee pain (VAS  $\geq 45$ ,  $< 75$ ) and 13 knee OA patients with mild peak pain (VAS  $\geq 10$ ,  $< 45$ ) were compared with 16 asymptomatic controls (VAS  $< 10$ ). Pain and function were assessed by the Western Ontario and McMaster Universities Arthritis Index (WOMAC) and the Brief Pain Inventory (BPI) questionnaires. The role of sensitization was assessed by pressure pain thresholds (PPTs), temporal summation, and conditioning pain modulation (CPM). The Foot posture index (FPI) was determined, and plantar pressure distribution was analyzed by measuring the maximum force applied in five masks of the foot (medial and lateral hindfoot, midfoot, and medial and lateral forefoot) using an in-shoe plantar pressure measurement system (pedar Insoles, Novel GmbH, Germany) during gait. Furthermore, the profile the tibiofemoral joint was graded based on frontal x-rays (K/L 0-4 grading scale).

### RESULTS

The maximum force in the medial forefoot mask tended to decrease in patients with increasing peak knee pain, assessed by VAS. There were significant correlations of maximum force applied at the medial forefoot to PPTs ( $r = 0.524$ ,  $P < 0.001$ ) (Figure 1), CPM ( $r = 0.532$ ,  $P < 0.001$ ), BPI ( $r = -0.325$ ,  $P < 0.05$ ) and WOMAC scores of pain ( $r = -0.425$ ,  $P < 0.01$ ),

stiffness ( $r = -0.386$ ,  $P < 0.01$ ), and physical function ( $r = -0.378$ ,  $P < 0.05$ ). The maximum force applied at the medial hindfoot was correlated to FPI score ( $r = -0.394$ ,  $P < 0.01$ ) and K/L grade ( $r = -0.330$ ,  $P < 0.05$ ). Additionally, the maximum force applied by the medial forefoot correlated to control tests (on *m. tibialis anterior* and *m. extensor carpi radialis*) of PPTs ( $r = 0.554$ ,  $P < 0.001$ ) and CPM ( $r = 0.561$ ,  $P < 0.0001$ ), and the maximum force applied by the lateral hindfoot correlated to control tests of temporal summation ( $r = -0.367$ ,  $P < 0.05$ ) and CPM ( $r = 0.322$ ,  $P < 0.05$ ).



**Figure 1** Mean knee pressure pain thresholds (PPTs) in relation to the maximum force in the medial forefoot mask ( $r = 0.524$ ,  $P < 0.001$ ).

### CONCLUSION

Modulated plantar pressure observed in tibiofemoral OA patients cannot be contributed to one single parameter, but is rather a consequence of a complicated combination of several parameters, including degenerative changes and sensitization. The results confirm that examinations of foot biomechanics, in particular measurements of plantar pressure distributions, are relevant in future investigations of medial tibiofemoral OA.

### REFERENCES

- Felson, Arthritis Research & Therapy 11:203, 2009  
 Henriksen *et al.*, The Knee 13:445-50, 2006  
 Lidtkje *et al.*, Journal of the American Podiatric Medical Association 100:178-84, 2010.



## ANKLE JOINT LOADING DURING LANDING ON INCLINED SURFACES - MECHANICAL EFFECT OF ANKLE BRACES IN INJURY PRONE SITUATIONS

Ilias Theodorakos (1), Jan Rueterbories(1), Michael S. Andersen(2),  
Mark de Zee(1), Uwe G. Kersting(1)

1. Department of Health Science and Technology, Aalborg University, Denmark
2. Department of Mechanical and Manufacturing Engineering, Aalborg University, Denmark

### INTRODUCTION

Ankle and knee sprains are the most common injuries in sports causing an economic burden for health care systems (Fong et al 2007). Past studies (Baumhauer et al 1995) investigated risk factors; however the underlying injury mechanics remain unclear. A detailed investigation of the injuring situation might support the understanding of the underlying injury mechanics.

Ankle braces are often used to prevent ankle injuries and they seem to be specifically beneficial for players with a previous injury to the ankle or established instability (Gross & Liu 2003).

Towards the assessment of the effectiveness of an ankle brace in injury prone situations, we investigated the effect of the landing leg (preferred vs. non-preferred) and the landing manner (jumping vs. stepping), on measured ground reaction force (GRF) and supporting forces applied to the ankle by a brace.

### SUBJECT AND METHOD

One healthy male subject (1.7m, 70kg, 28years, preferred leg: right) performed a landing task from a height of 40cm on a robotic force platform (van Doornik & Sinkjaer 2007) which can be inclined by  $\pm 20^\circ$ . This procedure was repeated for the preferred and non-preferred leg. In a further repetition we modified the manner of landing of each leg: *stepping* resembles stair descending, where push off is established by the opposite leg, while *jumping* describes push-off and landing by the same leg. The ground reaction forces were measured by a force plate (AMTI, 2000Hz). Brace support forces were obtained by pressure system (Novel, pliance, 128Hz) below the brace.

### RESULTS

The extent of variability of the mean peak value, of the vertical to the wooden surface component, of the force was higher when the landing task was performed with the non-preferred leg than with the preferred one (10.4% vs. 4.4% for the stepping and 4.7% vs. 4.5% for the landing). Moreover the stepping manner of landing had less variability than the

jumping one when using the preferred leg (4.4% vs. 4.5%) (Figure 1).

Brace support forces were higher when the landing task was performed with the preferred leg than with the non-preferred one ( $23.174 \pm 8.9$  (SD) vs.  $16.18 \pm 3$  N). They were also higher when the subject used the stepping manner ( $23.174 \pm 8.9$  (SD) vs.  $19.788 \pm 6$  N).

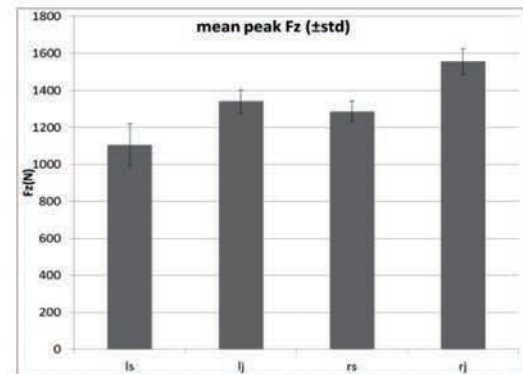


Figure 1: Mean peak value of the normal to the wooden surface component of the force (N) for the one condition. l: left leg, r: right leg, s: stepping, j: jumping.

### CONCLUSION

The choice of the preferred or non-preferred landing leg and the manner of landing affected both the GRF and the brace supporting forces.

This study indicates that it is safe to ask a subject for his preferred leg in order to perform the landing task with the stepping manner.

### REFERENCES

- Baumhauer et al, Am J Sports Med 23:564-70, 1995.  
Fong et al, Sports Med 37:73-94, 2007.  
Gross et al, J Orthop Sports Phys Ther 33:572-7, 2003.  
van Doornik et al, IEEE Trans Biomed Eng 54:1696-702, 2007

\*Corresponding author. Email: ith@hst.aau.dk.

## BODY COMPOSITION INFLUENCES INDIRECT BUT NOT DIRECT MEASURES OF FOOT ARCH STRUCTURE IN ADULT FEMALES

Lloyd. F. Reed (1), Scott. C. Wearing (2,3)

1. Institute of Health & Biomedical Innovation & School of Clinical Sciences, Queensland University of Technology, Queensland, Australia
2. Centre of Excellence for Applied Sport Science Research, Queensland Academy of Sport
3. Faculty of Health Sciences and Medicine, Bond University, Queensland, Australia

### BACKGROUND

Whether indirect measures of arch structure, such as those derived from pressure footprints, are confounded by body composition is controversial. This study compared the effect of body mass index (BMI) on direct and indirect measures of arch height.

### METHODS

Thirty one adult females (age,  $41 \pm 11$  years; height,  $166 \pm 7$  cm, weight  $74 \pm 15$  kg, BMI,  $26.9 \pm 5.6$  kg.m<sup>-2</sup>) were classified as normal weight (NW, BMI: 18.5–24.9), overweight (OW, BMI: 25–29.9) or obese (OB, BMI:  $>30$ ), based on principal BMI cut-offs (WHO, 1995). An EMED-SF platform (spatial resolution, 4 sensors.cm<sup>-2</sup>) was used to obtain dynamic plantar pressure data at preferred walking speeds. Three trials were recorded for the right foot. The arch index was calculated from contact areas, as the ratio of the central third of the foot relative to the total area (less the toes). Caliper measures of navicular height were used for direct assessment of static arch height (Gilmour *et al*, 2001). Foot volume was estimated under thermoneutral conditions using a revised water-displacement method (Henschke *et al*, 2006). The coefficient of variation for repeat measures of volume and arch height were  $1 \pm 0.6\%$  and  $3 \pm 2\%$ , respectively.

### RESULTS

Although foot volume was 25% greater in OB than NW ( $P < .01$ ), the contact area of only the midfoot was significantly higher in OB compared to NW ( $P < .01$ ); resulting in a greater arch index in OB (Fig 1). In contrast, neither navicular height nor peak pressure beneath the rearfoot, midfoot, forefoot or digits differed significantly between groups (Table 1). Multiple regression showed that BMI ( $\beta = 0.42$ ,  $t = 3.1$ ,  $P < .01$ ) and navicular height ( $\beta = 0.51$ ,  $t = 3.3$ ,  $P < .01$ ) were both independent predictors of the footprint-based arch index ( $R^2 = 0.59$ ,  $F_{3,29} = 12.2$ ,  $P < .01$ ).

Table 1: Effect of body composition on pressure data

	NW	OW	OB
Stance Phase (ms)	864 $\pm$ 80	894 $\pm$ 90	973 $\pm$ 113*
Arch area (cm <sup>2</sup> )	16 $\pm$ 8	25 $\pm$ 5	26 $\pm$ 4*
Heel pressure (kPa)	321 $\pm$ 57	299 $\pm$ 94	285 $\pm$ 54
Arch pressure (kPa)	91 $\pm$ 26	122 $\pm$ 26	143 $\pm$ 22
Ball pressure (kPa)	468 $\pm$ 172	486 $\pm$ 295	516 $\pm$ 174

\* Significant difference between OB and NW ( $P < .01$ )

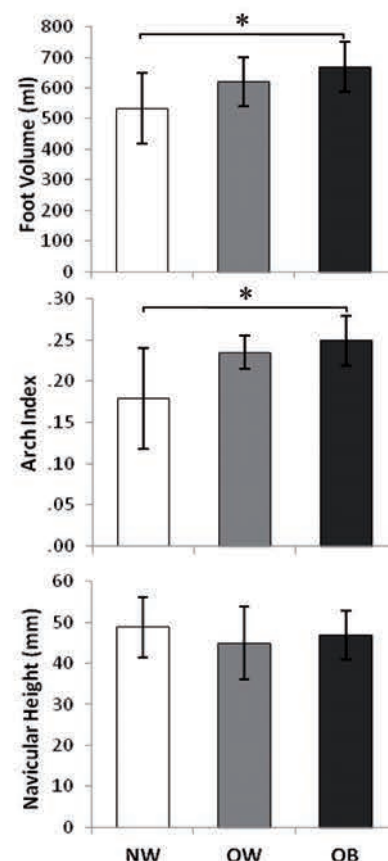


Fig 1: Foot shape in normal (NW), overweight (OW) and obese (OB). \* significant difference at  $P < .01$ .

### CONCLUSION

Differences in body composition may selectively distort footprints in adult females. These findings are consistent with our previous research in which foot structure was measured radiographically (Wearing *et al*, 2012). Indirect footprint-based measures of arch height should, therefore, be interpreted with caution when comparing groups of varying body composition.

### REFERENCES

- Henschke *et al*, Foot Ankle Int 27:826-832, 2006.  
 Gilmour *et al*, Foot Ankle Int 22:493-498, 2001.  
 WHO, Technical Report, 854, 1995.  
 Wearing *et al*, J Orthop Res 2012 (in press).



# **USING PLIANCE AND A PLIANCE DEVELOPED SADDLE TO OPTIMIZE FIT AND COMFORT FOR A HORSE WITH SEVERE SPINAL ABNORMALITIES**

**Anne Crowell<sup>1,2</sup>, Annette Gavin<sup>3</sup>, Abigail Carter<sup>4</sup>**

1. George Mason University, M.S. Applied Physics Program, Fairfax Virginia
2. Pegasus Biomechanics, Stafford, Virginia
3. Hastilow Competition Saddles, Warfordsburg, Pennsylvania
4. Carter Dressage, Fredericksburg, Virginia

## **INTRODUCTION**

Basstrup's Disease or kissing spines syndrome is a degenerative condition in equines where the vertical spinous processes make contact and rub together. Inflammatory damage at the bone edges, bony remodeling, and compression of the surrounding soft tissue can result. The disease often causes severe pain and can greatly limit the performance of the affected horse. Correct long frame riding that activates the upper contraction system (Heuschmann, 2006) and pulls the spinous processes up and away from each other can be beneficial. Saddle fit for affected horses is critical as pressure on the horses back increases during the lifting of the spine.

The equine subject in this study suffers from a severe case of Basstrup's disease. Radiographs of the back show grade IV spinous impingement of the thoracic and lumbar vertebrae at the level of T14-L3. During riding, the horse had collapsed on several occasions. Initially it was unclear if the pain was solely due to the disease or if the saddle fit was a factor as well.

## **METHODS**

Pressure testing was performed on the horse's existing saddle using the Pliance saddle test system (Novel, Inc. MN). A new saddle, whose saddle tree has been designed using the Pliance saddle test system, was fit and pressure tested on the subject as well. Pressure data from both tests were then compared.

## **RESULTS**

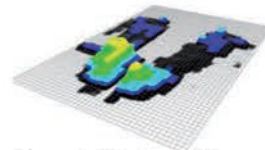
Results for the existing saddle showed asymmetric loading with substantially higher pressures toward the left and rear of the saddle (figure 1). Maximum average peak pressure at the walk was 19.750 kPa. A study at the University of Zurich associated saddle related damage at the walk at average pressures exceeding 15.3 kPa (von Peinen, 2010). Fit and performance for the existing saddle was assessed as poor.

The saddle with the Pliance designed tree produced a substantially better pressure distribution than did the previous saddle. Loading was symmetric, with very reasonable variations indicated throughout the entire scan (figure 2). The maximum average peak pressure was 12.500 kPa. Also, the new saddle had a

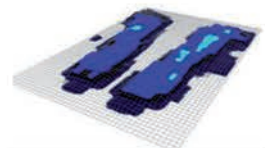
significantly larger bearing area than did the existing saddle. Panel contact area for the new saddle was 1471.875 cm<sup>2</sup>. Contact area for the existing saddle was 1012.500 cm<sup>2</sup>.

The horse's performance improved dramatically when ridden in the new saddle. The horse has been able to lift and flex his spine upward, and carry himself in a biomechanically correct manner. The basic gaits have improved, and the increased muscling in the horse's hindquarters suggests an enhanced ability to push forward. Video of the horse at the trot shows a positive diagonal dissociation between the fore and hind legs. This is an indicator that the trot is of good quality and well balanced (Clayton, 2003).

## **FIGURES**



*Figure 1: Existing saddle, asymmetric loading.*



*Figure 2: New saddle, symmetric loading.*

## **REFERENCES**

- Clayton, *The Dynamic Horse*, 27, 2003.  
Heuschmann, *Tug of War: Classical versus Modern Dressage*, 53-55, 2006.  
von Peinen *et al*, *Equine Veterinary Journal*, **42**, 650-653, 2010.



ESM 2012 Program at-a-glance

Time		Wednesday, August 1st	Thursday, August 2nd	Friday, August 3rd	Saturday, August 4th	Time	
07:15				<i>Pick-up, Lobby Hotel Radisson Blu</i>		07:15	
07:30	08:00	<b>Bus</b> from Hotel Radisson 7:30 to workshops at SMI	<b>Registration</b> Utzon Center	<b>Buses depart</b> from Radisson 7:30		07:30	08:00
08:00	08:30	<b>Registration</b> SMI, Aalborg Uni	<b>Welcome</b> Utzon Center			08:00	08:30
08:30	09:00	<b>Tours of the Labs</b> 8:45-10:00 SMI, Aalborg University	<b>Keynote lecture 1</b>		<b>Keynote lecture 3</b>	08:30	09:00
09:00	09:30				<b>Session 5</b> Modulation of gait	09:00	09:30
09:30	10:00		<b>Session 1</b> Orthotics			09:30	10:00
10:00	10:30	<b>Workshop I:</b> 10:00 - 11:00 <i>Aalborg University</i>	<b>Poster Session 1</b> & Coffee	<b>Networking day</b> <b>in Rebild</b> see also page 14	<b>Coffee</b>	10:00	10:30
10:30	11:00					10:30	11:00
11:00	11:30	<b>Workshop II:</b> 11:00 - 12:00 <i>Aalborg University</i>	<b>Session 2</b> Clinical Applications		<b>Session 6</b> Finalists II Methods	11:00	11:30
11:30	12:00					11:30	12:00
12:00	12:30	<b>Scandinavian companies - presentations</b> <i>Aalborg University</i>	<b>Lunch</b> <i>Utzon Café og Restaurant</i>			12:00	12:30
12:30	13:00			<b>16:30 Bus depart</b> from Rebild to Radisson Blu Hotel	<b>Lunch</b> <i>Utzon Café og Restaurant</i>	12:30	13:00
13:00	13:30	<b>Lunch</b> <i>SMI Atrium</i>				13:00	13:30
13:30	14:00		<b>Session 3</b> Finalists I Methods		<b>Keynote lecture 4</b>	13:30	14:00
14:00	14:30	<b>Workshop III:</b> 14:00 - 14:45 <i>Aalborg University</i>			<b>Session 7</b> Diabetes	14:00	14:30
14:30	15:00	<b>Workshop IV:</b> 14:45 - 15:30 <i>Aalborg University</i>	<b>Poster Session 2</b> & Coffee		<b>Coffee</b>	14:30	15:00
15:00	15:30			<b>Dinner &amp; Exhibition</b> <i>Nordkraft, Aalborg</i>		15:00	15:30
15:30	16:00	<b>Workshop V:</b> 15:30 - 16:15 <i>Aalborg University</i>	<b>Keynote lecture 2</b>		<b>Session 8</b> Exercise and Loading	15:30	16:00
16:00	16:30				<b>MPP Award</b>	16:00	16:30
16:30	17:00	<b>Bus 16:30</b> from SMI to Hotel Radisson	<b>Session 4</b> Exercise&Athletic Footwear			16:30	17:00
17:00	17:30				<b>Closing remarks</b>	17:00	17:30
17:30	18:00	<b>Registration</b> <i>KUNSTEN, Museum of Modern Art</i>		<b>Banquet Dinner</b> <i>Utzon Center</i>		17:30	18:00
18:00	18:30	<b>Opening Reception</b> <i>KUNSTEN</i>				18:00	18:30
18:30	19:00					18:30	19:00
19:00	19:30		<b>Evening Event</b> <i>Boat Princess Juliana, Aalborg Harbour</i>			19:00	19:30
19:30	...					19:30	...